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ARCHITECTURAL POTTERY

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BRICKS, TILES, PIPES, ENAMELLED TERRA-COTTAS, ORDINARY AND INCRUSTED QUARRIES, STONEWARE MOSAICS, FAÏENCES, AND ARCHITECTURAL STONEWARE

BY

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PREFACE BY

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WITH 5 PLATES, 950 ILLUSTRATIONS IN THE TEXT, AND NUMEROUS ESTIMATES

TRANSLATED FROM THE FRENCH BY

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PREFACE.

M. LEFÊVRE'S work on the use of pottery in architecture appears at a fortunate moment, for natural building materials such as wood and stone already show signs of exhaustion in those districts where they formerly existed in abundance.

The rapid exhaustion of quarries from which we have drawn for years obliges us to get supplies from greater and greater distances, and so to raise inordinately the price of building-stones. We can only replace them by calling to our aid artificial materials, such as iron, brick, terra-cotta, cement, etc.

Ancient examples of the substitution of terra-cotta for stone are frequent in Persia. Jules Laurens and Dieulafoy have shown them to us in the imposing buildings which they have sketched and reproduced from the remarkable ruins excavated on the sites of ancient cities like Suse.

In the Milan district, in Italy, the cloisters of the Carthusian Monastery at Pavia, the Milan Hospital, and many other fine buildings, present splendid examples of the use of bricks and terra-cotta decoration.

Even while the sculptors of the Renaissance were carving from stone the lacework, arabesques, and statues which make the buildings of that period gems of architecture, the genius of the Della Robias, that family of artists, was achieving a triumph for decorative pottery.

But generally, it is those countries which lack building-stone and possess clay, that especially offer us interesting edifices constructed of artificial materials.

Of all those substances, terra-cotta is undoubtedly the one best adapted for elegant work, and the architect should never lose sight of it, even in the simplest constructions.

Besides the artistic effect given by the use of terra-cotta materials, and due to their preparation and colour, cheapness is undoubtedly a strong argument in their favour.

The resource of the future, then, is incontestably a judicious use of pottery. But we must not content ourselves with copying ancient objects; we must adapt the shapes and decoration of terra-cotta materials to the requirements and taste of our own period. For that purpose it will be necessary to thoroughly understand the infinite resources which pottery offers to builders.

A description of the processes of manufacture will therefore be of undoubted interest. This M. Lefèvre appreciates, and in his book he studies step by step the manufacture and applications of all the ceramic products used in architecture. From the common brick, to terra-cotta enamelled in brilliant colours, and including tiles, quarries, etc., everything is carefully described in detail.

This book will, without any doubt, be profitably studied by manufacturers, builders, and architects, in a word by all who are interested in architecture.

J.-C. FORMIGÉ,
Architect to the Government and
to the City of Paris.

TRANSLATORS' PREFACE.

THE principal difficulty in the translation of a work which abounds in technical details is the correct interpretation of technical terms.

In "La Céramique du Bâtiment" there occur several names for which there is no English equivalent, that is to say, no technical expression generally used and understood by the English potter. Among such may be mentioned the terms "Enfumage," "Petit Feu," and "Grand Feu" in the description of kilns. We have preferred to leave these and most similar names in the original French rather than to attempt an English rendering which could only be clumsy and inaccurate.

Some machines and processes have different names in different districts but no definite designation common to the whole trade; to these we have endeavoured to give names which, while not perhaps strictly technical, will sufficiently explain their nature to all readers.

Thus to the machine called a "Tailleuse" in French we have, on the advice of a leading firm of brick-makers, affixed the name "Mixing Mill."

To mark the distinction between a "Tuile" and a "Carrière" we have translated the latter as a "Quarry," although the term "tile" would be equally applicable to it as to the former.

Similarly "vernis" has been translated "varnish" to distinguish it from other glazes, notwithstanding the fact that the word would not be commonly used in this sense.

We are indebted to several firms of brick and tile makers for kind advice, which we hereby gratefully acknowledge.

The work of M. Lefèvre is, however, so comprehensive and of such magnitude that it has not been possible for us to obtain information as to all the processes described in it, and there may be some terms which might have been rendered with more technical accuracy.

In spite of such shortcomings, we shall venture to hope that our translation may prove as clear and readable as the subject-matter undoubtedly is instructive.

K. H. B. AND W. M. B.

THE METRIC AND BRITISH SYSTEMS.

TABLE OF COMPARISON.

Money.

£1 = 25 francs. 1 franc = 9½d., about.
1 franc = 100 centimes.

Weight.

1 gramme = 15.43 grains.
28⅓ grammes = 1 ounce av.
1 kilogramme = 1000 grammes = 2.20 lbs. av.

Length.

1 metre = 100 centimetres = 39.37 inches
Roughly speaking, 1 metre = a yard and a tenth.
1 centimetre = four-fifths of an inch.
1 kilometre = 1000 metres = five-eighths of a mile.

Metres.	Decimetres.	Centimetres.	Millimetres.	Inches.	Metres.	Decimetres.	Centimetres.	Millimetres.	Inches.
.001	.01	.1	1	.039	.06	.6	6	60	2.362
.002	.02	.2	2	.079	.07	.7	7	70	2.756
.003	.03	.3	3	.118	.08	.8	8	80	3.150
.004	.04	.4	4	.157	.09	.9	9	90	3.543
.005	.05	.5	5	.197	.1	1	10	100	3.94
.006	.06	.6	6	.236	.2	2	20	200	7.87
.007	.07	.7	7	.276	.3	3	30	300	11.81
.008	.08	.8	8	.315	.4	4	40	400	15.75
.009	.09	.9	9	.354	.5	5	50	500	19.69
.01	.1	1	10	.394	.6	6	60	600	23.62
.02	.2	2	20	.787	.7	7	70	700	27.56
.03	.3	3	30	1.181	.8	8	80	800	31.50
.04	.4	4	40	1.575	.9	9	90	900	35.43
.05	.5	5	50	1.968	1	10	100	1000	39.37

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PART I.

PLAIN UNDECORATED POTTERY.

POTTERY IN ARCHITECTURE.

CHAPTER I.

CLAYS.

§ 1. CLASSIFICATION—GENERAL GEOLOGICAL REMARKS.

Definition.—Clays are mineral substances, very extensively found in nature, soft to the touch, yielding under slight pressure, and of very varied colours: white, yellow, red, green, blue, grey, or black, according to the nature of the impurities contained in them. They possess as common and distinctive characteristics: first, their plasticity, which causes them to preserve received impressions—this quality varies with the nature of the clay; second, their property of forming with water a tenacious paste, with a peculiar smell, which paste can be modelled, and hardened by drying. The clay then clings to the tongue, and if it is again suitably moistened, becomes plastic once more; but if it is exposed to a high temperature, its nature completely changes; it can no longer be diluted with water, it undergoes a considerable contraction, and, at the same time, acquires occasionally a very great degree of hardness; for certain clays, when highly baked, will give a spark on being struck by steel.

Chemical Composition.—Pure clay, which is white and refractory, is composed of silica, aluminium, and water, this latter being in a state of combination and not as a hydrate. The proportions of these three substances are very variable, and lie within the following limits:—

Silica	45 to 75 per cent.
Aluminium	38 to 16 ,,
Water in combination	6 to 19 ,,

These pure clays are very rare. Ordinary clays, such as are found in great profusion, contain other substances in more or less quantity; especially iron oxides and sulphuret (pyrites), salts of lime, particularly the carbonate (limestone) and the sulphate (gypsum), magnesium, alkalies (potash and soda), organic substances, etc. We shall refer later on to the properties given to clays by the presence of these ingredients.

Classification of Clays.—The difficulty of this classification is due to the different aspects in which their chemical composition, physical characteristics, and geological origin may be considered.

Authors generally follow the classification suggested by Brongniart about 1840; by it clays are thus divided:—

1. *Kaolin Clays.* — White, yellowish or greyish, refractory, thin to the touch, and not easily forming a paste with water.

2. *Plastic Clays.*—Refractory, dense and greasy to the touch, forming with water a tenacious, supple, and dough-like paste.

3. *Smectic Clays or Fuller's Earths.* — Full and greasy to the touch, frothing when beaten up with water, of variable colour, fusible in the porcelain kiln, absorbing oils easily, hence used in cloth-fulling.

4. *Figuline Clays or Potter's Earths.*—Same physical properties as the plastic clays, but coloured and much more fusible.

5. *Marls or Effervescent Clays.*—Not very stable, but very fusible, forming with water a brittle paste which effervesces under acids.

6. *Ochreous Clays.* — These contain a large quantity of oxides of iron, yellow and red, and are used as colouring-matter.

Several objections may be made to this nomenclature: the kaolins are badly defined; to make a special class of plastic clays is to infer that plasticity exists little, if at all, in other clays; whereas, as a matter of fact, potter's earths possess this property to as great a degree as the plastic clays; also there is no mention in the list of a clay, or clay-like earth, which is very extensively found on the surface of the globe,

and, wherever it exists, is used in the manufacture of bricks; this is the "lehm" or tableland slime, a mixture of clay and very fine quartz, coloured with an oxide of iron. Another classification has been proposed by M. le Chatelier. This savant has affirmed that, when clays are heated, they undergo molecular changes; one of these, dehydratation, manifests itself by an absorption of heat which takes place at different temperatures according to the nature of the clay. Moreover, some of them show, at about 1000° C., a peculiar phenomenon attended by a sudden elevation of temperature. Combining these two facts, M. le Chatelier has found that the great majority of clays can be assigned to five very distinct classes which do not generally overlap one another. These are:—

		Absorb. heat at.	Set free heat at.
1. Allophanous	SiO_2, Al_2O_3, Aq	220° (noticeable)	1000° (sharp).
2. Kaolin	$2SiO_2$, Al_2O_3, $2H_2O$	770° (very marked)	1000° (slight).
3. Halloysite	$2SiO_2$, Al_2O_3, $2H_2O$. Aq	200° (not very marked) 700° (very marked)	1000° (sharp).
4. Pyrophyllite	$4SiO_2$, Al_2O_3	770° (fairly noticeable) 850° (doubtful)	Not at all.
5. Montmorillonite	$4SiO_2$, Al_2O_3. Aq	200° (very important) 770° (less marked) 950° (doubtful)	Not at all.

However interesting these facts may be scientifically, it seems to us difficult to adapt them to the technical point of view from which we are looking. We shall content ourselves with modifying Brongniart's classification as follows:—

1. *Kaolin Clays.* — White, generally crystallised, refractory, undergoing no contraction in firing.

We must not confuse with these very characteristic substances certain white refractory clays, wrongly called kaolins, which may in the last resort be used for making china, but which have not the well-defined properties of the true kaolin.

2. *Refractory Clays.* — Yellowish or greyish white, usually soft and greasy to the touch, and forming with water a paste which is often tenacious, dough-like, and supple.

3. *Figuline Clays or Potter's Earths.*—Plastic like the foregoing, but coloured, becoming generally red in baking, and much more fusible than the preceding classes. Some contain

no limestone, the rest a small quantity which does not at the most exceed 2 or 3 per cent.

4. *Clayey Marls or Effervescent Clays.*—Of variable plasticity, very fusible, and characterised by the presence of a large quantity of limestone; according to the amount of this limestone, they are called clay marls or calcareous marls; it is to it that they owe their property of effervescing under the action of acids.

5. *Lehm, Tableland Slime, or Brick-earth.*—An intimate mixture of clay and very fine quartz, coloured yellow or red by oxides of iron. When the lehm is calcareous, it takes the name of *loess.*

6. *Smectic Clays or Fuller's Earths.*

7. *Ochreous or Ferruginous Clays.*

The latter two kinds are not used in pottery.

Geological Origin of Clays.[1]—Clays are usually found in fairly regular seams in nearly all stratified soil which has been formed in the midst of fresh or sea water; for there are frequently found in them the fossil remains of sea or fresh water shells, as well as other fossil organic débris. The clays are formed by the deposit of substances formerly in suspension within a liquid in motion.

These substances come from the destruction of primitive volcanic rocks by the combined action of the atmospheric agents: wind, water, air, heat, cold, etc. Nevertheless, we shall see that other more complex agencies, of a chemical nature, must have had a share in the formation of certain clays, especially of the enormous deposits of kaolin like those of Limousin in France and Cornwall in England.

The majority of volcanic rocks contain a common ingredient called *felspar*, which is a combination of silica with different metals: aluminium, potassium, sodium, calcium, etc. Such are the *pegmatites* (Haute-Vienne, Pyrenees, Cornwall), formed of quartz (crystallised silica) and felspar, the *granites* and *gneiss*, which are both composed of quartz, mica, and felspar.

[1] The following description and figures are borrowed from that excellent work by M. de Lapparent, *Traité de Géologie*, 3rd ed., Paris, 1893, Masson et Cie. The eminent geologist has been kind enough to revise this summary, and I thank him heartily for doing so.—L. L.

The typical felspar contains—

Silica	65 per cent.
Aluminium	18 ,,
Potassium	17 ,,

Under the influence of water charged with carbonic acid, the alkaline silicates existing in felspar are decomposed into alkaline carbonates or earthy alkalines, and give up silica, which remains in veins in the dry rock, where the current of filtering water is too slow to carry it off in suspension. The aluminium silicate which remains engenders a product resembling kaolin, hence the name of *kaolinisation* has been given to this mode of disintegration of felspar rocks. When the rock contains grains of quartz, these are not affected, and as the water draws from them the clay element formed by the kaolinisation of the felspar, it follows that, under the sole influence of the filtering water, the majority of granitic rocks are changed into sand. In our climates, this change can be effected down to fifteen or twenty metres below the surface. What proves conclusively that it is the work of the moist air assisted by variations of temperature, is that it does not occur to an appreciable extent in Egypt, where the equable and dry climate leaves granite almost intact after the lapse of centuries.

If the kaolinisation of felspar rocks, caused by meteoric water, has yielded here and there some veins of clay pure enough to be called kaolin, this superficial action has not been capable of forming great layers of kaolin like those of Limousin, and we must therefore find another explanation of their existence.

Origin of Kaolin.—Kaolin is almost always found in the neighbourhood of tin deposits; but, with tin ore, there always appear either quartz and granite with white mica, or pegmatite invariably accompanied by fluorine compounds.

This coincidence has led people to think that tin ore is formed by the action of a powerful mineralising agent which might be fluorine. As this metalloid violently attacks the silicates, it has been concluded that its appearance has reacted

upon the rock containing them, that is to say, the pegmatite, so as to transform it into kaolin. This theory, suggested by Buch in 1824, with reference to the kaolin at Halle in Prussia, has been taken up by Daubrée, and definitely adopted by de Lapparent in his *Geology*.

Fig. 1 represents a section of the tin deposit of Weisse Andreas in Saxony. The containing rock is formed by a mica

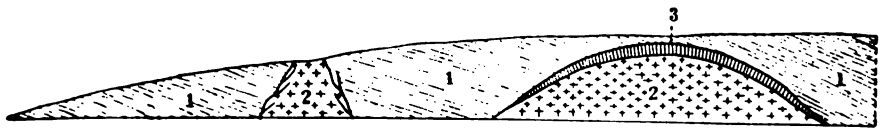


Fig. 1.—Stanniferous Deposit at Weisse Andreas (Saxony).
1, miscaschiste; 2, tin ore; 3, stockscheider.

schist (quartz and mica more or less mixed with felspar) which, in the neighbourhood of the tin ore, has become transformed into granite, the felspar being kaolinised and the crystals of quartz imbedded at right angles in the schist, reaching a length of several decimetres. This granite has received the name of *Stockscheider*, and is worked for the manufacture of porcelain.

Refractory clays other than kaolin, such as those of Bray and in the neighbourhood of Vierzon (France) and Andenne (Belgium) are usually connected with deposits of fresh-water sand, in the midst of which the clay forms not seams properly so called, but nests, accumulations, and veins. Opinion is divided as to their origin; some see in them the action of meteoric waters on volcanic rocks; then the transportation or mechanical displacement of the kaolin so formed, which, at that period, was more or less adulterated with foreign substances. Other authors, and these not less numerous, attribute the formation of these clays to the influences of temperature acting either on granitic masses at a considerable depth, or on sediments of the Primary Epoch.

The other clay deposits are the result of the agglutination of substances which have been in suspension for a long time, in the form of a more or less impalpable slime, and which came from the destruction of pre-existing rocks by the action of sea or river water or atmospheric agencies. The deposits were made during

the period of the formation of sedimentary soil, therefore clays are found in all stratified ground.

Origin of Lehm or Brick-earth.—Lehm, which dates from the quaternary or modern epoch, covers large surfaces, especially in the neighbourhood of large uneven masses.

According to de Lapparent (*Traité de Geólogie*), the trickling of rain-water, when very abundant, degrades the neighbouring slopes and carries down, according to the strength of the flow, sometimes fine soil and sometimes fragments of stone; this would be sufficient to account for the formation of lehm, which is therefore also called tableland slime. This trickling, many times repeated, was produced by streams of water thin enough to allow free access to the air; that is to say, the formation of the slime took place in an *oxidising atmosphere*, whence this peculiarity that the clay contains no organic substances, and that the iron in it is, for the most part, in the form of peroxide, as is shown by the yellow colour of the mass.

We know that glacier-earths and river-mud, which are similar to lehm, but are formed without access of air, have a bluish grey colour, due to the organic matter and the nature of the iron-salts contained in them.

As for the red slime which, showing signs of having been hollowed out by water, covers the deposits of lehm, and forms the *beetroot soil* of the North, it is also employed for the manufacture of brick, but opinions are divided as to its origin. It contains no limestone, but in many places contains angulous splinters of white oxidised flint.

According to Wood, the red slime with splintered flint is the result of the alternation of frost and thaw on the surface of the earth; the changes of temperature lightened the crust and splintered the flints, which, being situated in a frequently muddy mass, acquired the white oxidisation, a sign of change. This transformation, taking place at different depths, must have produced those signs of hollowing which are observed on the horizontal parts, while on the inclined parts there was a real hollowing-out, due to the slipping of the slime which was reduced to pulp by its mixture with snow.

Geological Situation of Clays.—It is known that sedimentary rocks are divided into four groups according to the age of their formation: primary, secondary, tertiary, and quaternary or modern period. Each group is subdivided into systems which form stages, according to the age of their deposit.

GROUPS:	*Primary.*	*Secondary.*	*Tertiary.*	*Quaternary.*
SYSTEMS:	Precambrian	Triassic	Eocene	
	Silurian	Jurassic	Neocene	
	Devonian	Cretacian		
	Carboniferous			
	Permian			

In all these systems clays are found, even in the primary. We will point out to which geological stages the principal clay deposits belong.

Primary Epoch.—PERMIAN SYSTEM.—Large deposits of clays and variegated marls in Russia.

Secondary Epoch.—TRIASSIC SYSTEM.—The *Keuper* stage of this system is represented by the *variegated marls* of the Vosges and Moselle; these are clayey marls of strongly contrasted colours, in which red and green predominate.

JURASSIC SYSTEM.—In France, in the *liasic* system, are found the Bayeux clays which are used in the manufacture of fired china, and reach a height of 15 to 20 metres. In England the Bradford clays belong to the *mediojurassic* series, and to the *suprajurassic*, Oxford clay, which is tenacious, of a

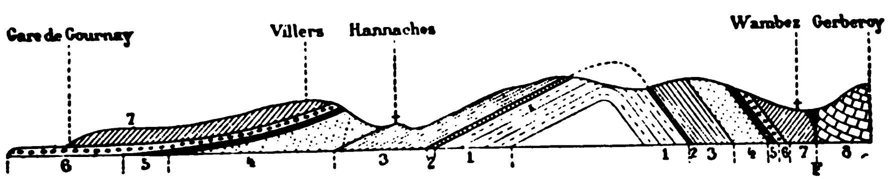


Fig. 2.—Section of the Bray District between Gournay and Gerberoy.

1, lower clays (upper Kimeridge); 2, lithographic limestone; 3, upper clays (upper Kimeridge); 4, sand, sandstone, and limestone marls; 5, clay (Portland); 6, sandstone; 7, lower cretaceous earth; 8, chalk; F, excavation.

dark blue colour, sometimes bituminous, and reaches a thickness of 150 to 200 metres. The clay is also found in the Calvados, in France, where, mingled with fine sand, it serves as support to the rich pasturage of the Auge country. At Honfleur it is 20 metres

thick. At Villequier (Seine-Inférieure) an excavation to a depth of 40 metres brings to light the so-called Kimeridgian clay situated a little higher, which is worked for brick and tile manufacture.

The Bray country possesses clays, little worked, however, belonging to the suprajurassic system (*Portland* and *Kimeridge* stages) and arranged as in Fig. 2.

CRETACEOUS SYSTEM.—The *neocomian* stage of the same infracretaceous series includes considerable deposits of clay which are of great industrial importance.

In England is found the blue or brown Weald clay, whose thickness reaches 300 metres.

In France, the very interesting clays of the Bray country belong to the same stage, but have very different properties according to the position they occupy. The section in Fig. 3 shows their arrangement.

In the middle neocomian are found the stone clays, called in the Bray district *terre à pots* or *terre à grès*, which have been worked from time immemorial at la Chapelle-aux-Pots (Oise), Saint-Germain-la-Poterie, Savignies (Oise), for the manufacture of stoneware articles, chimney-pots, fountains, bonbonnes, ink bottles, etc. They are extracted from open pits or by means of shafts.

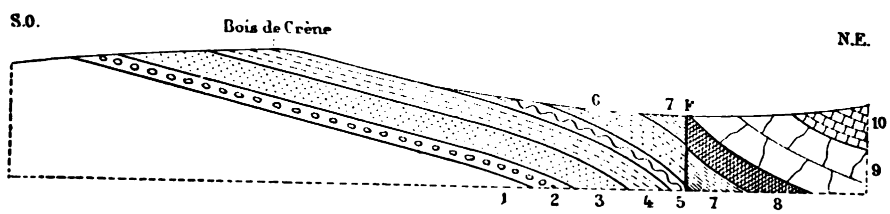


Fig. 3.—Transverse Section (1 in 10,000) from the Northern Outskirts of Bray, near Glatigny.

1, lower Portland and Kimeridge; 2, upper Portland; 3, white sands and refractory clays; 4, ferruginous sandstone and potter's clays; 5, streaked clay; 6, green sands; 7, gault and gaize; 8, cenomanian chalk; 9, turonian chalk; 10, senonian chalk; F, excavation.

The refractory clays, found in the Bray country from Forges to Gournay, belong to the lower neocomian. They are more or less mixed with white sand, and are especially abundant in the neighbourhood of Forges. The best variety is of a bluish silver-grey, which whitens on exposure to air. The seams are very

irregular, and the products of different pits are extremely diverse. The masses of clay, in the midst of sand, take often the shape of isolated balls. At Forges these masses are large and numerous, while at Serqueux, only two kilometres distant, the sand contains hardly any clay.

The upper neocomian presents, also in the Bray district, a considerable outcrop of streaked loam, or marbled pink clay, worked for the manufacture of tiles, pipes, and paving squares. This is also an ingredient of the mixtures used for the manufacture of stoneware.

The most important pits are on the road from Auneuil to Beauvais and on that from Forges to Rouen.

At Desvres (Pas-de-Calais) is also found a layer of clays 20 metres thick, some grey and violet, others streaked with red and grey, which are often refractory, and appear to correspond to the English Weald deposit.

To the *albian* stage of the *lower cretacian* series belong 30 or 40 metres of green sand found in the Bray district, and worked for brick-making.

Tertiary Epoch. — The tertiary rocks contain numerous deposits of plastic clays, which are especially abundant in the Paris basin, where they are found above the chalk.

EOCENE SYSTEM.—*Eocene Series.*—The Thanet stage of this system presents, at Lille, a bed of grey or black plastic clay, 15 to 20 metres thick. But it was particularly after the invasion of the Thanet Sea (from the Thanet promontory to the mouth of the Thames) that the plastic clays were formed in consequence of a period of lagoons and estuaries which forms the sparnacian stage.

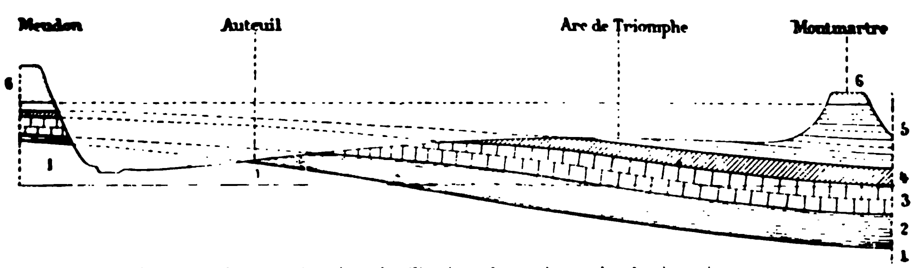


Fig. 4. Diagram showing the Tertiary Deposits under Paris (1 in 10,000).
1, chalk and pisolithic limestone; 2, plastic clay; 3, limestone gravel; 4, Beauchamp sands and Saint-Ouen limestone; 5, gypsum and green clays; 6, Fontainebleau sands.

At Varengeville, near Dieppe, a plastic grey clay is worked for the manufacture of tiles and bricks; in Artois, in Flanders, in Picardy, in Hainault, plastic clay is often found collected in holes and irregular veins in the midst of sand. These clays bear signs of the conflict between the fresh water and the sea at the sparnacian period; but when we come to the Paris basin, there is no longer anything but fresh-water deposits. The thickness of the plastic clays of this district is very diverse; it is slight at Meudon, but below Saint-Denis extends to 50 metres.

At the base there is found a bed of clay streaked with red and grey, then the true bluish grey plastic clay divided into two strata by a fine, clayish, and ligneous quartz sand, called Auteuil sand. Everywhere in the neighbourhood of Paris these clays are worked for tiles, bricks, pipes, etc.

At the extremity of the Ile-de-France, in the Gâtinais country, a plastic clay, variegated with bright tints, occupies pockets in the chalk; it is used in the neighbourhood of Montereau for the manufacture of porcelain.

West of the Paris basin, on the Eure plateaux, there are found white sands streaked with yellow and red with veins of clay which are frequently red and usually form pockets in the chalk. In these pockets, peculiar chemical reactions have taken place which in certain places have caused the formation of *halloysite* (a variety akin to kaolin), and this is employed at Breteuil-sur-Iton for the manufacture of stoneware. The refractory clay of Abondant, near Dreux, also forms part of the sparnacian stage.

After this stage follows the *yprésian* (from Ypres in Flanders), which includes the London clay, a brown or brown-grey clay reaching a thickness of 250 metres, and known in Flanders by the name of *Ypres clay* or *Flanders clay*. Its thickness is about 100 metres; it is plastic and of a bluish grey colour, like the Roubaix clay which appears to belong to the same stratum.

As type of the eocene series, we will mention also the *flint clay* of le Perche. It is a conglomerate of natural flints coming from the chalk, and encrusted in a red and white clay which appears to have a chemical origin. This conglomerate is found

also in the Sologne and Blaisois districts, where it extends in places to a thickness of 30 metres. In the forests of Châteauneuf and Senonches, the conglomerate of plastic clay passes under quartz sands with lustred sandstones mingled with coarse kaolin sands and white or variegated pure clays. This variety of the plastic clay stage is continued in the neighbourhood of Châteaudun and round Evreux, where the clay sometimes becomes refractory, while the lustred sandstones are accompanied by iron ore formerly worked in the valley of the Iton.

Oligocene Series.—To this series belong the clays or green marls of the Paris basin, the depth of which does not exceed 4 to 5 metres. They extend to the neighbourhood of Étampes and Ferté-Alais, and are worked everywhere for brick and tile manufacture at Fresne-lez-Rungis, Sannois, and Orgemont. They contain no pyrites, and consequently give out no sulphurous acid in baking like certain plastic clays from the western side of Paris. This is what distinguishes the Vaugirard brick-earth from the clay called Ménilmontant or Belleville.

To the oligocene series are attached the Marseilles clays, the order of which is as follows:—

Aquitanian . .	Yellowish Marseilles clays with pudding-stones.
Stampian . .	Red clays of Saint-Henri and Lestaque.
Sannoisian . .	White lacustrine limestone. Blackish ligneous clays.

The refractory clay of Andenne (Belgium) is also of the same series, as is too the sometimes sandy, sometimes clayey, deposit which covers a large part of North Germany to a height of 160 metres.

Some clays of special formation belong to the oligocene period. Under the plain of la Bresse at Bourg (Ain) they form a continuous layer of 28 metres thick and of various colours: white, yellow, marbled, red, blue, or green. They are of siderolithic origin and are found above iron ore.

NEOCENE SYSTEM.—*Miocene Series.*—The sands and clays of la Sologne are of this series; they reach a thickness of 40 metres on the right bank of the Loire, and join the so-called kaolin sands of the Eure plateaux, which are formed of grains of quartz, combined by means of a clay cement easily loosened

by water. In company with plastic clays, chemically very pure, they fill cracks or funnels.

Pliocene Series.—This is represented, in the Morbihan, by blue or grey clays found at Saint-Jean-la-Poterie, Redon (Ille-et-Vilaine), Saint-Gildas-des-Bois (Loire-Inférieure).

In the neighbourhood of Chalon-sur-Saône, fluvial sands are found mingled with variegated clays, which are often refractory, and are worked at Saint-Léger-sur-Dheune and Montchanin (Saône-et-Loire).

Quaternary or Modern Rocks. — *Pleistocene Epoch.* — To this period belongs the *lehm* (brick-earth or tableland slime),

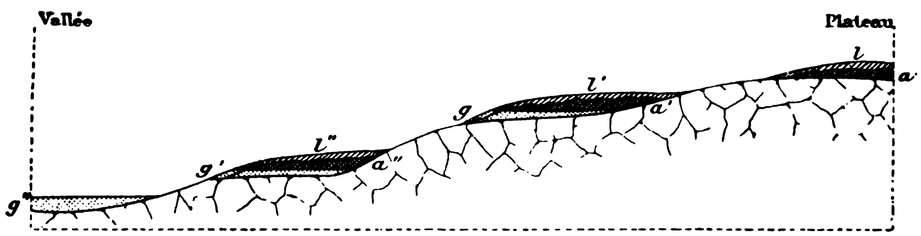


Fig. 5.—Normal Section of the Valleys in the North of France.
g,g',g'', gravels at the bottom of the different levels ; *a,a',a''*, lehm ;
l,l',l'', red ooze with splinters of flint.

and the *loess* (calcareous lehm). Generally these alluvial deposits are in terraces of different heights from the bottoms of valleys to the highest points of a watershed, as can be seen from Fig. 5. The sands and gravels accompanying the lower alluvions become rarer as one ascends; but more or less angular flints are always to be met with. The ooze is hollowed out, or sometimes covered with another reddish brown slime, the formation of which we have explained.

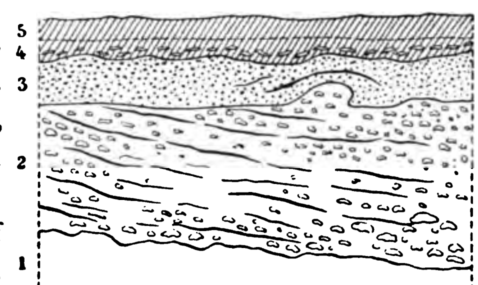


Fig. 6.—Section of the Alluvions of the Somme Valley.

1, chalk ; 2, sands and gravels ; 3, rich sand ; 4, brown ooze with angular splinters of flint ; 5, brick-earth.

On lower ground the composition of the alluvions is fairly constant (Fig. 6).

The distribution of the

lehm is independent of the altitude, and is found from the level of the sea to a height of 1500 metres in Europe, and in China to a height of 3500 metres.

In Europe it is especially abundant in the valleys of the Rhine, Danube, and their tributaries.

Hainault, Brabant, and Limburg are completely covered with it. Although less thick in the north of France, it is found over a large part of the tablelands between the valley of the Loire and Flanders, where it reaches its maximum of thickness. It is found in Hungary, Moravia, and Roumania; but not in Russia, or on the Baltic or North Sea coasts.

The pampas of la Plata and the basin of the Mississippi are covered with it, and, finally, in China it attains a thickness of 400 to 500 metres.

Wherever it exists, lehm is used in the making of bricks, as also is loess when it is not too calcareous.

§ 2. GENERAL PROPERTIES OF CLAYS—COMPOSITION.

Physical Properties.—*Plasticity.*—That is to say that clays are able to preserve the shape which is given them; a valuable quality utilised in the manufacture of ceramic productions. This property varies with the nature of the clays, being highly developed in some, such as potter's earths, and slight in the thin or limestone clays and lehm.

It is generally admitted that the plasticity of clays varies with the proportion of *combined* water which they contain. This water enters into the very composition of the clays, which contain as much as 18 or 19 per cent. of it, and only leaves them at a red heat, while the *hygroscopic* water, or quarry water, which does not play the same part in the properties of the clays, mostly leaves them when dried in the air. The 2 or 3 per cent. remaining after this drying are expelled by a heat of 100° C.

But the clay, so heated and deprived of its hygroscopic water, recovers its properties when suitably moistened, whereas, if deprived of its water of combination, it acquires new properties:

hardness, sonorousness, and inability to regain its former plasticity.

The testing of the plasticity of a clay is not an easy matter; daily practice alone can teach it.

Experience shows the quantity of cleansing matter required, in order to leave a good paste which will mould well and dry without losing shape.

For plastic clays cannot be worked alone on account of their adhesiveness and of the change of shape, accompanied by cracking, which they undergo while being dried.

Contraction.—Clays as they come from the pit contract when dried; if warmed, they continue to contract more or less sensibly according to their nature. The contraction becomes considerable when the clay has been made into a paste with water, and may be as much as a quarter of the linear dimensions. Usually, in the case of brick-clay, the total shrinkage, in drying and firing, amounts to 5 to 15 per cent. of the linear dimensions. Shrinkage takes place twice: during the air-drying, and during firing. It varies according to the mode of the latter process, and the method of manufacture.

Plastic and fusible clays undergo most contraction, but for different reasons; the former because they contain a great deal of water. They experience the greatest shrinkage at the moment when they lose this water; that is to say, at about 110° C. A higher temperature causes little contraction, because the infusible molecules cannot get closer to one another. Fusible clays, on the other hand, undergo shrinkage at that period of the firing, because the molecules weaken and approach one another to form a homogeneous whole, of a more or less close texture according to the temperature.

The shaping of the paste plays an important part in the shrinkage. Thus articles made of soft clay, that is to say of clay soaked in water, undergo more contraction than those formed from hard or semi-hard clay, that is to say from clay merely moistened with water.

Articles made by expression undergo more contraction than those manufactured by simple compression. In the latter,

inequalities of pressure cause inequalities of shrinkage, hence there is warping when the pieces are fired. This is especially noticeable in tiles and other articles which have a large surface in comparison to their thickness.

Shrinkage takes place perpendicularly to all the surfaces of the pieces; that is to say, they shrink simultaneously in length, breadth, and thickness. But sometimes it happens that it acts unevenly in consequence of pressure on the piece when being baked. Thus pieces placed in the lower part of the kiln, and resting one upon another, so supporting the weight of all the upper layers, may increase in length and breadth while diminishing in height. These deformations are especially noticeable in highly baked bricks; they bear no trace of external fusion, but their fracture has a compact texture resembling that of stoneware, and evidently due to the drawing together of the molecules under the action of heat and pressure.

A thorough knowledge of the shrinkage of clays is of great importance in the manufacture of pottery, not only to give the proper dimensions to moulds and dies, but also with regard to the adhesiveness of glazes, as we shall show later on. Experience alone can teach us, since contraction varies with the clay. In expression-machines we allow an average of 10 per cent. difference between the brick issuing from the die and the same brick when baked. For the moulds in presses, working with unblended clay, only 5 per cent. is allowed.

Fusibility.— A clay is said to be refractory when it supports without melting a temperature of about 1800° C., which is that borne by china-clays. The most refractory clays are those which most resemble pure unadulterated silicate of alumina. The presence of metallic oxides, such as the oxide of iron, lime, potash, soda, etc., makes clays fusible by reason of the formation, at high temperatures, of complex silicates, which are all more or less fusible. Lime, which when pure is very refractory, makes an infusible clay fusible if mixed with it. The carbonate of lime, or limestone, added to a clay in the proportion of one-half or three-quarters, renders it fusible.

The oxides of iron which colour clays with various tints,

make them fusible by reason of the formation, during baking, of silicate of iron.

To summarise, then, foreign bodies in clays tend, at a high temperature, to combine with the silicate of alumina, the base of clay, to form with it complex silicates which are generally more fusible. Hence the necessity of never subjecting ordinary pottery to too high a temperature. Nevertheless the heat must be sufficient to form complex silicates, yet not great enough to melt them. In this way we obtain an impervious, hard, compact substance, similar to stoneware.

If the temperature is pushed too high, the complex silicate melts like glass, and binds together the different articles being fired. Sometimes, in a badly managed kiln, a sudden access of heat softens the pieces and binds them into one single mass, which has to be removed from the kiln with the tongs. In a continuous kiln, the walls of which are not made of refractory substances, we have seen a part of the vault become welded to the pieces being fired under a tremendous access of heat, and break away from the arch under the action of shrinkage; these are accidents easily avoided by careful watching and regular stoking.

Chemical Composition. — *Analysis of Clays.* — We have already shown the limits within which the different ingredients of clay vary. In the following tables we have collected a certain number of analyses of the best-known clays. These analyses have usually been made with pure clays which in most cases have been cleaned.

They do not show, therefore, the impurities which may be contained in clays, and hence have more interest for the savant than for the manufacturer.

We must also not forget that they can only serve as a rough guide, since the composition of clays varies from one place to another, even in a distance of a few metres. Hence, whenever a manufacturer wishes for information as to the chemical composition of his clays, he should take, with every precaution, a sample from each bed, the physical appearance of which seems different from the others.

Locality.	Hygroscopic Water.	Composition of Clays when dried at 110° C. Water in Combination.	Silica.	Aluminium.	Oxide of Iron.	Lime.	Magnesium.	Alkalies.	Physical Properties and Applications.
I. Refractory Clays.									
A. *Kaolins.*									
France—									
Brittany	...	13.00	48.00	36.00	...	...	...	2.00	
Limousin	...	13.10	48.00	37.00	...	...	...	2.50	
Nièvre	...	12.60	49.00	36.00	...	..	...	1.60	
Pyrenees	...	11.50	48.00	34.60	traces.	0.84	...	2.15	
England—									
Cornwall	...	13.00	48.35	36.00	0.75	...	...	0.96	
Germany—									
Dolau (near Halle)	...	12.76	48.15	37.03	0.60	0.27	0.30	0.82	
Russia	...	12.60	48.00	36.00	...	...	...	2.40	
China	...	11.20	50.00	33.70	...	...	...	1.90	
B. *Various Clays.*									
Germany—									
Eifel	3.50	13.00	46.60	39.30	...	...	...	...	Refractory.
Grossalmerode (Duchy of Hesse)	0.43	14.00	47.50	34.37	1.24	0.50	1.00	...	Grey and plastic, below the ligneous earths, very pure.—Mixed with quartz sand, is used for Hessian crucibles, which bear sudden changes of temperature without cracking.
Lautersheim (Prussia)	...	13.56	49.00	33.00	2.10	2.00	0.20	...	White and plastic.—Fine pottery of Mettlach and Sarreguemines.
Loshhayn (near Meissen, Saxe)	2.70	11.70	61.52	20.92	0.50	traces.	4.97	...	Blackish, mixed with quartz.—Saggers (Meissen Manufactory).
England—									
Devon	...	11.20	49.60	37.40	...	...	...	...	Grey, plastic, base of English flint-ware.
Stourbridge	...	17.34	45.25	28.77	7.72	0.47	...	...	Black, not very plastic, comes from coal-field, infusible.—Crucibles for melting steel, and refractory bricks.
Austria—									
Gottweith (near Krems)	1.00	10.00	65.60	20.75	2.00	1.55	traces.	...	Dirty green with red spots.—Saggers (Vienna Manufactory).
Theuberg (Bohemia)	0.49	10.00	58.39	27.74	traces.	0.74	1.00	...	Plastic, grey, below the lignite clays.—Saggers (Elbogen Manufactory).
Belgium—									
Andenne	...	19.00	52.00	27.00	2.00	...	...	...	White plastic. Glassware pots, crucibles, faiences.
Angleur	8.30	14.30	46.30	39.50	...	...	...	...	Refractory.

Locality.	Hygroscopic Water.	Composition of Clays when dried at 110° C. Water in Combination.	Silica.	Aluminium.	Oxide of Iron.	Lime.	Magnesium.	Alkalies.	Physical Properties and Applications.
Antragues . .	...	9.00	71.00	19.00	...	...	...	...	Grey and plastic. — Glass-ware pots, gas retorts, refractory bricks.
DENMARK—									
Isle of Bornholm .	0.27	5.92	72.50	19.50	1.00	0.50	0.50	...	Plastic, grey, superior to chalk. — China saggers (Copenhagen Manufactory).
FRANCE—									
Abondant (near Dreux, Eure-et-Loir). . .	...	13.10	50.60	35.20	0.40	...	...	...	White, plastic, very refractory. — Crucibles for melting steel, china saggers.
Belin (Ardennes) .	...	1.27	63.57	27.45	0.15	0.55	...	traces.	Plastic, grey infusible. Faïences (Douai).
Boulogne (Pas-de-Calais) . .	2.24	6.28	69.42	18.00	0.95	2.00	3.27	...	Hard, greyish brown, infusible. — Fine faïences and pottery.
Breteuil (Eure) .	12.50	14.30	48.30	35.60	...	...	...	..	Refractory. — Bricks and refractory pieces.
Dourdan (Seine-et-Oise). . .	...	9.20	60.60	26.39	2.50	0.84	...	...	Plastic, infusible.
Echassières (Allier)	...	16.40	49.20	34.00	...	...	...	...	Plastic, white. — Hard porcelains.
Étrepigney (Jura) .	...	9.96	70.00	18.50	0.50	0.75	traces.	...	Rich, greenish grains of quartz, infusible. — Faïences (Doubs).
Forges - les - Eaux (Seine-Inférieure)	...	11.00	65.00	24.00	traces.	...	...	...	Plastic, grey. — Stoneware articles, glass-ware pots, refractory products, fine faïences, common faïences.
Gaujacq (Landes) .	0.42	14.50	46.50	38.10	...	traces.	...	...	Plastic and white. — China saggers (Villedieu).
Hayange (Moselle)	...	7.50	66.10	19.80	6.30	...	...	...	Yellow, sandy. — Refractory bricks.
Huelgoat (Finistère)	5.10	14.30	47.90	38.00	...	...	...	...	Refractory.
Klingenberg (Vosges)	...	16.00	48.32	32.48	1.52	1.64	...	...	Plastic, grey. — Glass-ware pots, glass pots.
Labouchade (Allier)	...	12.00	55.40	26.40	4.20	...	...	...	Hard, yellowish white. — Glass-ware pots.
La Malaise (Haute-Vienne) . .	1.55	15.00	52.55	26.50	0.55	3.00	1.50	...	Plastic, with red veins, infusible. — China saggers (Limoges Manufactory).
Laumède (Dordogne) . .	4.00	13.60	48.70	36.50	...	...	...	...	Refractory.
Leyval (Charante-Inférieure). .	...	12.00	52.00	31.60	4.40	...	...	...	White, marbled with red. — Glass-ware pots.
Miglos (Ariège) .	6.50	14.00	46.30	36.70	...	...	...	...	Refractory.

Locality.	Hygroscopic Water.	Composition of Clays when dried at 110° C.							Physical Properties and Applications.
		Water in Combination.	Silica.	Aluminium.	Oxide of Iron.	Lime.	Magnesium.	Alkalies.	
Montereau (Yonne)	...	10.00	64.40	24.60	traces.	...	..	...	Plastic, light grey, very variable in composition. — Used for English faïence clay.
Provins (Seine-et-Marne) . .	...	0.30	57.00	37.00	4.00	1.70	...	...	Plastic, whitish. — Refractory bricks, china saggers.
Retourneloup (Seine-et-Marne)	2.27	16.96	42.00	38.96	0.85	1.04	0.17	...	Plastic, grey, with red veins. Sevres saggers.
Salavas (Ardeche) .	1.45	11.05	58.76	25.10	2.50	...	2.51	...	Plastic, rose-coloured, turning grey in the kilns.—Crucibles for smelting steel.
Savignies (Oise) .	...	...	65.00	31.00	2.00	traces.	2.00	...	Plastic, black, above chalk.— Native pottery.
Russia—Gloukoff . .	2.71	16.50	46.35	37.00	..	...	0.15	...	White, plastic. — Base of St. Petersburg china.
Valendar . .	0.52	6.75	65.27	24.19	1.00	...	2.02	...	Plastic, greyish.
II. Pottery Clays.									
England—Longport . .	...	10.60	54.50	16.50	3.13	3.37	...	...	Plastic, violet coloured. Staffordshire bricks.
France—Arcueil (Seine) .	...	11.01	62.14	22.00	3.00	1.68	traces.	...	Plastic, black, below coarse limestone.—Paris pottery.
Livernon (Lot) .	...	18.00	49.00	24.00	6.26	2.00	...	...	Red. — Pottery, imitation of Etruscan pottery.
Vaugirard (Seine) .	...	14.58	51.84	26.10	4.91	2.25	0.23	...	Plastic, blackish, veined.—Paris pottery.
III. Marly Clays.									
France—Grandpré . .		13.13	58.50	13.50	8.33	5.19	1.35	...	Tiles and pottery.
Saint-Henri (near Marseilles). .	...	21.70	38.00	24.00	4.50	11.00	0.80	...	Tiles and pottery.
IV. Lehm (*Vegetable Mould*).									
Nordlingen . .		11.55	66.07	12.00	5.27	2.00	1.61	.	Reddish and sandy.—Bricks.

Influence of Various Bodies on the Properties of Clays.— *Potash and Soda.*—These exist nearly always in clay, sometimes as mere traces, sometimes in quantities of as much as 2 or 3 per cent.

Washing does not remove alkalies from the clay, and it is probable that these substances come from the felspar or mica parts scattered in the clay in excessively fine particles which remain, like the clay itself, in suspension in the water.

At a moderate temperature the alkalies have no effect, but at the temperature of china-kilns they act as fluxes; hence ordinary brick paste, fired at a high temperature, should only contain a small proportion of alkalies, otherwise they would be too fusible. But it is very different with stoneware and porcelain pastes. Alkalies (felspar, pegmatite, etc.) are added to the former in order to weld together the particles of the substance, and to give it that peculiar appearance characteristic of stoneware, and to the latter in order to obtain the characteristic transparency of porcelain.

Lime.—The presence of this substance increases the fusibility of clays, and consequently diminishes the value of the refractory earths. But in those products which are fired at a less high temperature, if the lime does not exist in too large a proportion, it forms silicates which do not effervesce, and which play a part in the transparency of certain chinas. In the hard French china we find 3 to 6 per cent. of lime, a quantity which is increased to 10 or 14 per cent. in soft porcelain.

Side by side with this chemical action, lime plays an important physical part in faïences. Its presence is indispensable for the adhesion of the stanniferous glaze with which faïence pastes are coated. Moreover, in faïences intended for stoves, it prevents cracks and increases their resistance to fracture. The proportion of lime in faïence pastes varies from 14 to 22 per cent.

The lime is always introduced in the form of more or less pure limestone. In the case of common pottery the quantity of limestone contained in the clay may rise as high as 10 or 12 per cent. without their workability being much affected, but it is

inconvenient to use more calcareous clays alone, because the products obtained split up under atmospheric influences. They are therefore used as antiplastics in combination with rich clays.

Magnesium.—Like lime and potash, traces of this occur in almost all clays, but those which contain it in appreciable quantity are rarely employed for pottery.

Oxides of Iron.—White clays contain none; these are the most uncommon (kaolins, refractory clays), the rest owe their yellow colour to the hydrated ferric oxide, and their red colour to the same oxide anhydrous. In firing it acts in two ways: it colours the pastes, and makes them fusible according to its quantity. Thus, common ferruginous stoneware contains from 5 to 8 per cent. of it. Above that proportion, the firing of the pastes becomes a delicate operation which must be stopped at the proper moment, otherwise the pieces will be deformed. The colour of pottery is not always proportioned to the quantity of iron contained in it; it depends upon the substances introduced into the paste, and especially on the state in which the iron is, a state which varies with the temperature and the atmosphere in which the firing took place.

Thus the same china paste containing oxide of iron sometimes bakes white and transparent, sometimes yellow and opaque, according to the atmosphere of the kiln. If the atmosphere is a reducing one, especially at the moment when the glaze begins to melt, the iron remains as an almost colourless silicate; if the atmosphere is an oxidising one, the iron may free itself in the form of ferric oxide; the quantity of oxide of iron being the same, the more silicious the paste is, the less is the coloration.

The influence of temperature is evidenced by this fact, that porcelains which are red when slightly heated, are transformed at a high temperature into transparent products, the oxide of iron becoming ferrous silicate.

In common faïences, charged with oxide of iron, a too great coloration of the biscuit, a coloration which would afterwards have to be hidden by a thick coat of opaque enamel, is avoided by firing in a reducing atmosphere (smoked).

The colour of the biscuit wares disappears superficially when

they receive a glaze containing borax, because this latter dissolves the oxide. This is the case with English flint-ware, which is slightly coloured as biscuit, but becomes white on the application of the glaze.

In firing bricks, differences of colour are sometimes noticed depending upon their position in the kiln; these differences are caused by the varied oxidising and reducing power of the atmosphere due to the state of the fire.

Sulphuret of Iron (Pyrites).—This occurs in many clays, sometimes in the form of lumps or grains, sometimes scattered through the mass in an impalpable state; it is probable that the colour of certain plastic clays is caused by its presence.

In firing, the sulphuret of iron is decomposed into sulphurous acid which escapes, and into an oxide which, by attacking the surrounding parts, forms hollows in the products. Several clays in the neighbourhood of Vaugirard contain such large quantities of sulphuret of iron that their use has had to be forbidden on account of the volumes of sulphurous acid given out by the brickworks.

Sometimes there are found in these clays beautiful crystals of iron sulphate caused by the oxidisation of the sulphuret. This chemical decomposition is sometimes so pronounced that in the Soisson district these clays are worked to extract from them the sulphate of iron, and the double sulphate of aluminium and potassium (alum). The latter is produced by the sulphuric acid in excess formed in the oxidisation of the sulphuret attacking the clay.

Organic Substances.—These are of different kinds, and their quantity is very variable. Although non-existent or occurring in very small amounts in most clays, they are sufficient in others to colour them grey, brown, or black; and then in the firing these substances produce charcoal, or leave hollows within the products.

Finally, certain clays contain considerable quantities of matter resembling coal, and produce black pottery, which is rendered very refractory by the infusibility of the charcoal. Such are plumbago crucibles.

§ 3. WORKING OF CLAYS.

This includes the extraction of the clay and its transport to the place where it is to be manufactured. Arrangements for working differ according as the pits are open or underground.

I. *Open-air Pits.*

Extraction.—In the majority of brickworks using the plateau-slime, this extraction is of the most simple character.

Fig. 7. Workings of Plastic Clay at Arcueil.

If hand-machines are used like those in the neighbourhood of Paris (Fig. 89), they are placed near the beds of clay. With a special tool, resembling a wheelwright's spokeshave but with a blade higher and more curved, the workman cuts the earth in tiers, the earth when cut falling to the foot of the machine; it is used as it is, with a little moistening if too dry. When the distance between the bed of clay and the machine becomes too great, that is to say every week or fortnight, the latter is brought

nearer. When the bricks are hand-moulded (Flemish method) the clay is extracted beforehand, in order that it may undergo

Fig. 8.—Workings of Plastic Clay at Arcueil.

weathering. If ordinary brick-earth (lehm) is used, the shovel and pick are sufficient; if rich clays, however, are used, the process is as follows:—

The bed is opened by removing the vegetable earth or any other layer likely to injure the working. Sometimes these layers are fairly thick and entail somewhat heavy expense, and it is necessary in that case that the thickness of the bed should be great enough to repay this outlay. The bed is attacked in tiers (Figs. 7 and 8); the clay is extracted by means of two special tools, kinds of pointed hoe with edged sides; one with a short handle, the other with a longer one. With the first, the workman makes, in the perpendicular face of a tier, vertical then horizontal incisions which will form two dimensions of the slab. When a certain number of these incisions are made he cuts the clay mass vertically with the long-handled tool in a line parallel to the face of the tier and at about 15 centimetres (6 inches) from that face. In consequence of the previous cuts the slab of clay comes away, and the workman lays it down near him. Some may be seen to the left in Fig. 8.

By reason of its plasticity rich clay sticks to the tools and would prevent all working if care were not taken, to avoid this inconvenience, to dip the tool frequently into a bucket of water.

Transport.—Except in the case we have mentioned above, clay is rarely used at the place where it is extracted. It has always to be transported from the pit to the manufactory. If the distance is very short, or if local conditions prevent other means, the classic wheelbarrow is used. The English model is the best; the slope of the sides and their slight projection above the bottom place the centre of gravity much lower, relatively to the shafts, than in the French wheelbarrow, and thus render it more stable and easier to move.

Another important advantage is that the contents may be discharged by turning the barrow through an angle of 45°, resting it still upon the wheel, and without the man being obliged to move or let go the shafts; the discharge is therefore quick, and can take place on a narrow plank, which is an advantage in certain cases (Brabant, *Portefeuille de l'ingénieur de chemin de fer*). As the wheel of the barrow, by passing continually over the same line, would soon make a rut, especially in rainy weather, and would thus make wheeling difficult or even

impossible, it is run upon deal planks 22 centimetres (9 inches) wide and of different lengths. These planks are imbedded in the ground in order not to hamper the walking of the men. Sometimes plates of sheet-iron are substituted for these planks. In damp weather the clay, which always gets deposited on these wooden paths, makes them very slippery and even dangerous if on a slope. This inconvenience may be remedied by occasionally strewing some sand on them.

Transport by Tramway.—*A.* DRAWN BY MEN.—The transport of clay by means of wheelbarrows is certainly the most onerous method. In all cases where it is possible to do so, a portable tramway should be substituted for them. These tramways (the best-known type of which is the Decauville) are now comparatively cheap. (The 40 centimetre gauge costs 3 fr. 10 c. per metre, and the 50 centimetre gauge 3 fr. 20 c.)

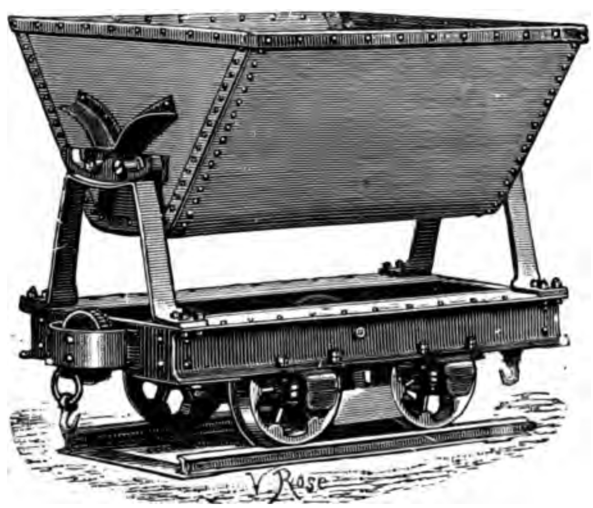


Fig. 9.—Earthwork Waggon.

For man traction, which is the simpler method if the distance is not too great, a waggon is used containing 250 litres for the 40 cm. gauge or 300 litres for the 50 cm. gauge, making the volume of about five or six wheelbarrows.

The waggon is emptied very simply by tipping it over on one side as shown in Fig. 10. These waggons, which are made entirely of iron, cost about 100 francs (1897).

B. Horse Traction.—If the distance from the place of extraction to the manufactory is somewhat great, and if the clay is worked on a slope, it is politic to use horse traction. Waggons like that in Fig. 11 are then used, furnished with a central buffer and couplings. The waggons contain 500 litres. A number of them, varying according to the inclination of the line and the strength of the horse, are coupled together. The horse soon gets accustomed to his work. It is well to make it easier for him by adopting a special (Fig. 13) harness, which permits him to develop the maximum of power. The swing-bar (Fig. 12)

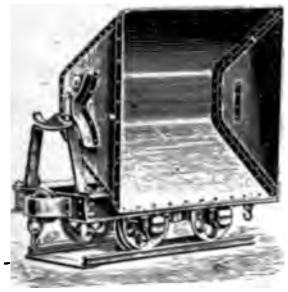


Fig. 10. - Earthwork Waggon Tipped.

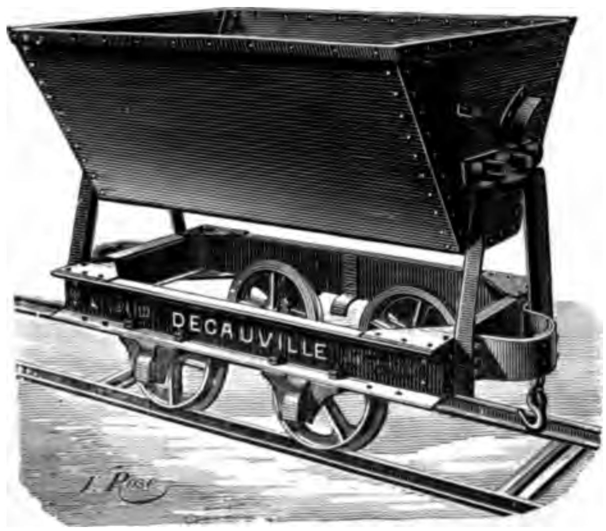


Fig. 11. - Earthwork Waggon with Central Buffer.

shown at the left of the figure is furnished with a leather cover to the coupling to prevent the horse's tail from being caught in it.

For the information of our readers we will calculate the net cost per cubic metre of the extraction of the clay and its transport over a certain distance by man and horse traction. This cost is evidently variable, depending upon the price of

labour and the difficulty of extraction. We will assume an ordinary clay easily dug and loaded.

Net Cost per Cubic Metre of the Extraction of Clay and its Transport by Waggon.—This net cost is made up of three parts:

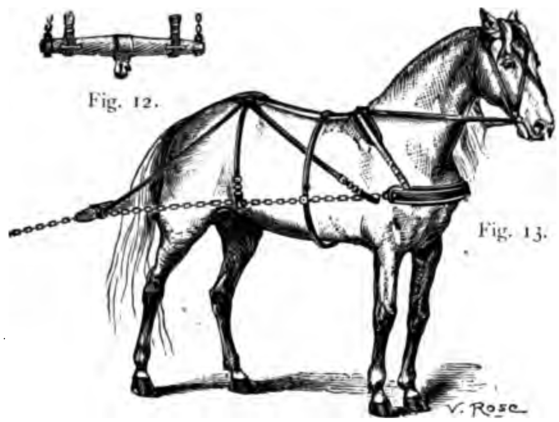


Fig. 12.—Whipple-tree with Coupling-cover.
Fig. 13.—Horse with Special Set of Harness for Waggon Traction.

one fixed, *i.e.* the cost of extraction, the two others varying according to the distance, and including the cost of traction, depreciation, repairs, maintenance, and interest on capital. We will estimate them in turn.

C. HAND TRACTION.—*Cost of Extraction.*—The extraction includes digging and loading. In ordinary brick-earth (lehm), a good digger can do 15 cubic metres per day of 10 hours, provided that he uses *l'abattage*; that is to say, digs below the mass to be removed, and when it only holds by cohesion, drives into the top of it, at a certain distance from the edge, stakes armed with iron points. The excavated mass falls away, and becomes lighter in falling; a few blows with the flat of a mattock make it fit to be shovelled.

The shoveller can treat 20 cubic metres in his day's work, but we will suppose that, being entrusted with the maintenance and displacement of the line, he only loads 15. We will take 40 centimes an hour as the cost of labour; that is to say, 4 francs per day of 10 hours.

The cost of a cubic metre of clay loaded on the waggon will therefore be . . . . 0.533 fr.

Cost of Traction.—A man of medium strength will push a waggon of .3 cubic metres at an average speed of 4 kilometres an hour on a straight road. If we take a distance of 100 metres, we shall have:

Journey loaded	2 mins.
Return empty	2 ,,
Unfastening, emptying, etc.	2 ,,
Total for a return journey .	6 mins.

That is to say, 10 journeys an hour; 100 journeys a day to transport about 30 cubic metres. The man pushing the waggon is paid about 3.50 fr. a day; that is to say, per cubic metre: $\frac{3.5 \text{ fr.}}{30} = 0.116$ fr. . . . . 0.116 fr.

Depreciation of Plant, Interest, etc.

100 metres of rails of .5 metres gauge		
15 ,, ,, ,, for shunting		
115	at 3 fr. 20 cmes.[1] . .	368 fr.
3 crossings	,, 45 ,, ...	135 ,,
1 turn-table	,, 60 ,, ...	60 ,,
8 waggons of 300 litres (Fig. 9)	,, 94 ,, ...	752 ,,
		1315 fr.
	Discount or rebate .	
	Total .	1315 fr.
Depreciation 10 per cent. per annum on 1315 fr. . . .		131.50 fr.
Interest at 4 per cent. on 1315 fr.		52.60 ,,
Oil and maintenance, taken at 2 per cent.		26.30 ,,
	Total .	210.40 fr.

Taking 300 working days and a daily output of 120 cubic metres, the annual output would be $300 \times 120 = 36{,}000$ c.m. If we suppose a less large extraction, or, as often happens, a stoppage of work in the winter for four months, we may reduce this estimate by a third, leaving 24,000 cubic metres.

In the first case, the cubic metre would cost $\frac{210.40}{36{,}000}$ fr. $= .0058$ fr., and in the second, $\frac{210.40}{24{,}000} = .0087$ fr.

We will take the latter and higher price . . . . 0.008 fr.

The cost of extracting and transporting a cubic metre of clay to a distance of 100 metres *on a level road* thus comes to . . . . 0.657 fr.

If there are any inclines, the cost is at once increased, and it is better to use horse traction.

HORSE TRACTION.—The cost of extraction and loading does not change, and is always, per cubic metre . . . 0.533 fr.

Cost of Traction. A horse of medium strength, walking beside the track and pulling with a chain, can haul on a level road of .5 m. gauge 8 waggons of

[1] We have taken the prices from the catalogue for September 1895 of the Decauville line and plant.

Brought forward . . . . 0.533 fr.

.5 cubic metres each; that is to say, 4 cubic metres. His speed is about 4 kil. per hour; taking a distance of 500 metres, we shall have—

Journey loaded	8 mins.
Return empty	6 ,,
Unfastening, coupling and uncoupling of waggons, shunting, etc., per journey	6 ,,
Total duration of return journey .	20 mins.

That is to say, 3 journeys per hour carrying 12 cubic metres
30 ,, ,, day ,, 120 ,,

A horse costs in food and maintenance about, per day . .	4 fr.	
Driver, 50 fr. a fortnight, per day	4 ,,	
Total .	8 fr.	
Which makes per cubic metre: $\frac{8}{120}$ = .066 fr.		.066 fr.

Depreciation of Plant, Interest, etc.

500 metres of .5 m. gauge.
35 ,, ,, for shunting.

535 ,, ,, at 3.20 fr.	1712 fr.
4 crossings at 45 fr.	180 ,,
1 turn-table at 60 fr.	60 ,,
16 waggons of 500 litres with buffers and couplings (Fig. 11), at 150 fr.	2400 ,,
1 set of harness for horse, with chain	90 ,,
1 horse (approximate price)	1200 ,,
	5642 fr.
Discount or rebate .	
Total .	5642 fr.
Depreciation at 10 per cent. per annum	564.20 fr.
Interest at 4 per cent. per annum	225.68 ,,
Oil and maintenance, 2 per cent. per annum	112.84 ,,
Total .	902.72 fr.

Supposing as before an annual extraction varying from 24,000 to 36,000 cubic metres, each metre will cost from $\frac{902.72}{36,000}$ or .037 fr. to $\frac{902.72}{24,000}$ or .025 fr.; we will take the higher estimate . . . . 0.037 fr.

Thus the cost of extraction and carriage for a distance of 500 *metres is, per cubic metre of clay* . . . . 0.636 fr.

that is to say, is less, for a distance five times as great, than that of man-power; but naturally the cost is greater if there are inclines. In this case, the amount carried per journey sinks.

On a slope of 2 centimetres per metre to 3 cubic metres (6 waggons)
,, 4 ,, ,, 2 ,, (4 ,,)
,, 7 ,, ,, 1 ,, (2 ,,)
,, 10 ,, ,, ½ ,, (1 ,,)

The cost of extraction and loading are the same, also the depreciation, and, the daily output being fixed at 120 cubic metres, we have: —

	Incline of 2 c.	Incline of 4 c.	Incline of 7 c.	Incline of 10 c.
Cost of extraction .	0.533 fr.	0.533 fr.	0.533 fr.	0.533 fr.
,, depreciation .	0.037 ,,	0.037 ,,	0.037 ,,	0.037 ,,
,, traction .	0.082 ,,	0.132 ,,	0.264 ,,	0.528 ,,
	0.652 fr.	0.702 fr.	0.834 fr.	1.098 fr.

It is therefore evidently advantageous to have only slight inclines; when the slope is more pronounced, traction by cable and inclined plane must be used.

Traction by Locomotives.—It may happen that the distance between the pit and the manufactory is such that it will be advantageous to replace horse by steam traction.

This occurs, for example, when a manufactory, in order to make use of an economical means of transport such as a river or canal, is installed on its banks, while the clay-pit is at some distance and a large daily output is required.

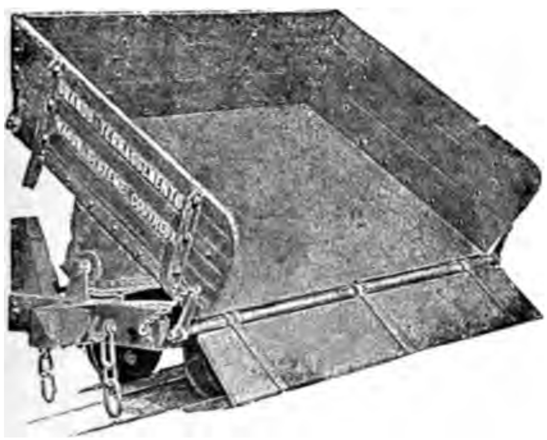


Fig. 14.—Waggon of the Couvreux System Tipped.

In this case a railway is laid down the gauge of which will depend upon the importance of the factory and its distance from the pit. Usually the 60 centimetre gauge will be sufficient, and wooden waggons will be employed of the type used for large earthworks, containing about a cubic metre and emptying by side-tip.

The framework is of oak and the body of poplar. A waggon of this kind costs 190 francs.

If the amount of clay to be carried daily is very great, waggons measuring two cubic metres and of the type represented in Fig. 14 can be used. The sides are wood, the base sheet iron resting on T-shaped iron bars. The price of a waggon of this type is 600 francs.

The side door is automatic and shuts itself when the waggon is raised by pulling down the other side.

The installation of locomotive traction is always expensive on account of the rails, which must weigh at least 9.5 kils. per metre.

To give some idea of the expense, we add an approximate estimate of the plant necessary for such a system.

A small locomotive like that represented in Fig. 15 weighs

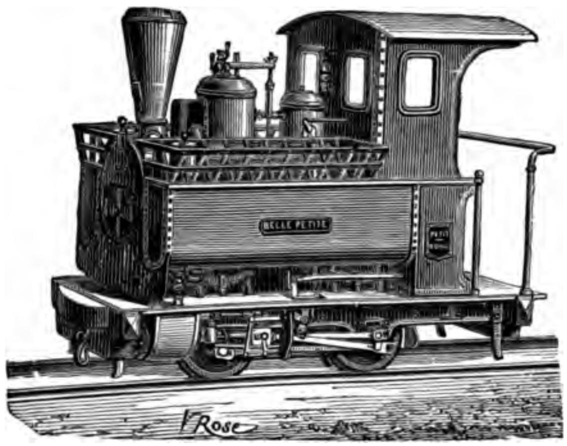


Fig. 15.—Three-ton Locomotive for .60 metre gauge.

3000 kilos (three tons nearly), and can haul a weight of 40 to 50 tons on the level at a speed of 10 to 12 kilometres an hour.

It costs		8.850 fr.		8.850 fr.
20 waggons (Fig. 14) of 2 cubic metres at 600 fr. each .				12.000 ,,
or 40 waggons of 1 cubic metre at 190 fr.		7.600 ,,		
Fixed outlay varying from		16.450 fr.	to	20.850 fr.
There must be added for each kilometre :				
For the permanent way at 7.15 fr. a metre	7.150 fr.			
Sundries—5 per cent., about	.350 ,,			
	7.500 fr.	7.500 fr.		7.500 fr.
Which makes for 1 kil. of line, with rolling-stock, from		23.950 fr.	to	28.350 fr.
Average about		26.000 fr.		
,, for 2 kil. of line, with rolling-stock, from		31.450 fr.	to	35.850 fr.
Average about		33.000 fr.		
,, for 3 kil. of line, with rolling-stock, from		38.950 fr.	to	43.350 fr.
Average about		41.000 fr.		
,, for 4 kil. of line, with rolling-stock, from		46.450 fr.	to	50.850 fr.
Average about		48.000 fr.		

These figures are sufficient to show under what circumstances a system of traction of such a kind becomes economical. In fact the annual expense for each distance will be—

		1 kil.	2 kil.	3 kil.	4 kil.
Depreciation . .	10 per cent.	2600 fr.	3300 fr.	4100 fr.	4800 fr.
Interest	4 ,,	1040 ,,	1320 ,,	1640 ,,	1920 ,,
Oil and maintenance .	2 ,,	520 ,,	660 ,,	820 ,,	960 ,,
		4160 fr.	5280 fr.	6560 fr.	7680 fr.

Fixing, according to the distance, the maximum cost of amortisation for each cubic metre carried at 0.075 fr., 0.15 fr., and 0.225 fr. respectively, it will be seen that the minimum annual bulk carried should be respectively—

55.400 c.m. 35.200 c.m. 29 100 c.m. 25.600 c.m.

Transport by Aerial Railway.—This system is used when the manufactory is situated below the level of the pit, and is

Fig. 16.

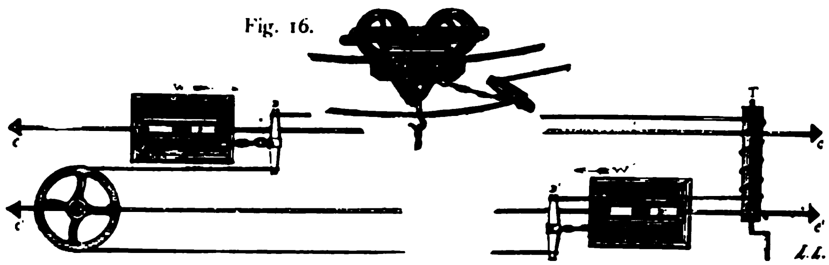


Fig. 17.

Fig. 16.—Suspension Pulleys.

Fig. 17.—Sketch showing the Working of Two-way Aerial Railway.

separated from it by an excavation. This occurs in the neighbourhood of Paris where, above the plaster-stone, brick-clay is often found. Under these circumstances, as the working of the plaster-stone leaves great hollows, and the brickworks are situated at the bottom of the hill, we want to pass the clay over the excavation by a simple and cheap method. The object is attained by the installation of a cable system. The full waggon suspended below a cable causes an empty waggon, which is suspended below another parallel cable, to ascend. The sketch in Fig. 17 explains the working of this aerial railway.

Two iron cables, C and C′, firmly attached at their extremities to fixed points, are stretched over the space to be crossed. On these cables run two grooved pulleys, which support beneath them the body of a waggon. The system of pulleys (Fig. 16) is joined by means of a cross-bar, B, to two other cables, C and C′. One of these, C′, passes over a return pulley, R, and joins the bar B′ of the descending waggon W′; the other, C, is turned

several times round the windlass T, and joins the bar B′ of the waggon W′.

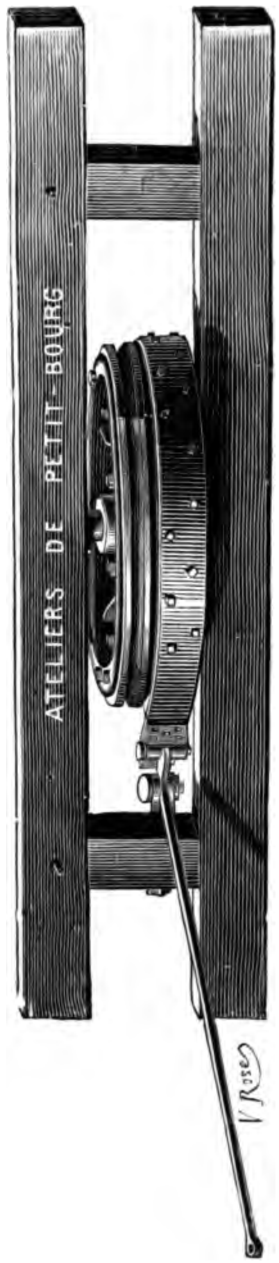


Fig. 18.—Return-pulley of an Inclined Plane, with Brake.

When the loaded waggon W′ is hung in its place, the system is set in movement by giving a few turns to the windlass T, so as to start the empty waggon W; and as soon as the apparatus has gained a certain speed, it is left to itself, the difference of weight causing the empty waggon to ascend. The next time, the windlass T is turned in the opposite direction so as to pull the empty waggon W′, and so on.

On the arrival of the waggons, they are placed on their framework, which has remained on the rails, and are taken, the full ones to the factory, the empty ones to the clay-pit.

Transport by Inclined Plane.—When there is no excavation to be crossed, and the manufactory is separated from the clay-pit by a gradual slope, or one that can be made gradual, it is advantageous to use inclined planes if the inclination is more than 8 or 10 in 100.

There are an infinite number of ways in which inclined planes can be arranged. The best and the most economical is that by cables where the apparatus is self-working, *i.e.* where the descending load pulls up the empty cars.

The installation comprises a pulley or a windlass, roller-frames, rollers, and a cable. In the one we describe, the pulley

over which the cable passes is furnished with a lever friction-brake (Fig. 18); it is placed between the uprights of a wooden frame which is fixed firmly into the ground, at the top of the incline, with stout piles, the axis of the pulley being quite vertical. After the pulley is placed the roller-frame with its four return rollers; two of these, with vertical axes, help to give the two branches of the cable their necessary distance and direction; and the two others, which have horizontal axes, are placed at the beginning of the slope, at the point where the plane changes from horizontal to inclined.

The rollers, which support the cable and prevent it from rubbing on the ground, are placed in a straight line at distances of from 5 to 10 metres according to the girth and tension of the cable.

The latter may be metallic (steel or iron), or of vegetable fibres (hemp, manille, agave); its length is that of the incline with 10 or 15 metres extra to enable it to go round the pulley and pass the roller-frame.

II. *Underground Clay-pits.*

When the bed of clay is covered by a quantity of foreign substance too great to be removed, or if it occurs in strata, it is cheaper to work it by shafts and galleries. Previous soundings will have informed us as to the thickness and probable extent of the bed. This is highly necessary, because the extraction by shaft being always expensive, it is evidently necessary that the outlay should be redeemed in a certain number of years.

The situation of the shaft is fixed by local circumstances, position of the bed, communication with the manufactory, etc. The size depends upon the method of extraction. In a large pit, a railway of 40 or 50 centimetres gauge will be used, hence the shaft must be square and large enough for two cars to pass one another; one ascending loaded, the other descending empty.

The square form also facilitates shoring up the shaft: for that purpose, by means of four beams, a square is formed, called "trousse," of the same size as the shaft.

The trousses rest against the earth; they are separated from one another by pieces of wood placed at the four angles, and if necessary in the middle of the bearing; these are called bearers. The distance from one trousse to another is more or less great according to the nature of the ground.

Shoring, properly so called, is carried out by introducing, between the trousses and the side of the shaft, oak planks of length equal to the vertical distance between the trousses. Behind these planks clay is heaped to prevent the entrance of water.

On reaching the bed of clay, a large reservoir is placed at the bottom of the shaft to collect the water coming from the galleries, which are bored through the whole thickness of the clay if it is not too great.

As a gallery is extended, it is lined by placing planks across it on the ground; on the ends of each plank two beams rest against the vertical sides of the gallery, and are joined at their upper ends by a strong oak plank, which thus forms a support to the roof.

These stays are placed more or less close together according to the consistence of the soil: in good ground they are placed at every metre, but in ground subject to landslip this distance is diminished, and the stays are joined by planks which support the soil.

The slope of the galleries will always be arranged so as to facilitate the flow of water towards the shaft reservoir. This reservoir will be emptied by pumps, or, better still, by using the water-tight bodies of waggons. The operation of emptying the reservoir is carried out every morning and evening before and after work.

A pit of this kind requires the same care as a mine: ventilation of the galleries, testing woodwork, etc. etc. The owner and manager must conform to the Mining Law of 21st April 1810, the articles of which referring to clay-pits we add below.

For the transport of clay through the galleries, a portable tramway will be used whenever possible, with waggons the bodies

of which have rings riveted to the four corners. The loaded waggon is brought under the hoisting-gear, the hooks on the four cable extremities are attached to the rings, and the car is raised. The descending empty car is put on the waggon-frame in its place. The same operation takes place at the surface.

This is evidently the most economical system, and there are very few cases of large extraction to which it is not applicable.

Note.—Extracts from the Mining Law of 21st April 1810, modified by the laws of 9th May 1866 and 27th July 1880.

Extract from the Mining Law of 21st April 1810.

I. MINES, ORE-PITS, AND QUARRIES.

ARTICLE 1. Masses of mineral or fossil substances, contained within the earth or on its surface, are classed, for purposes of regulation, under the titles of mines, ore-pits, and quarries.

ART. 2. Shall be considered as mines those known to contain in lodes, seams, or masses, gold, silver, platinum, mercury, lead, iron in lodes or seams, copper, tin, zinc, calamine, bismuth, cobalt, arsenic, manganese, antimony, molybden, plumbago, or other metallic substances, sulphur, earth or stone coal, fossil wood, bitumens, alum, and sulphates of metallic base.

ART. 3. Ore-pits comprise the ores of iron called alluvial, pyrite earths convertible into sulphate of iron, aluminous earths, and peats.

ART. 4. Quarries contain slates, sandstones, building and other stones, marbles, granites, limestone, plaster-stone, pozzalana, trass, basalts, lavas, marls, chalks, sands, flints, clays, kaolins, fuller's earths, potash earths, earthy matters and pebbles of all kinds, pyrite earths used as manure, all worked in the open air or with underground galleries.

. . . .

V. OF THE SUPERVISION OF MINES BY THE GOVERNMENT.

ART. 47. The engineers of the mines shall, under the orders of the Minister of Public Works and of the Prefect, exercise police supervision for the preservation of buildings and security of the soil.

ART. 48. They shall observe the manner in which the workings are carried out, in order either to point out to the owners its inconveniences, and how it may be improved upon, or to inform the Government of defects, abuses, or dangers which may exist.

ART. 49. If the working is reduced or suspended in such a way as to affect the public safety or the needs of consumers, the Prefect shall, after hearing the views of the owners, make a report to the Minister of Public Works in order that proper measures may be taken.

ART. 50 (*altered by the Law of 27th July* 1880). If the experimental or after-working of a mine be such as to endanger public safety, the preservation of the mine, the safety of the miners, the preservation of the lines of communication or of the mineral waters, the solidity of dwellings, the use of springs which supply towns, villages, hamlets, and public institutions, the Prefect shall take proper measures.

. . . .

VII. Regulations as to the Ownership and Working of Ore-pits.

Section I. *Ore-pits.*

Arts. 57 and 58 (*replaced by Article* 3 *of the law of* 9*th May* 1866).

Art. 3. The Articles 57 and 58 of the same Act are modified as follows :—

Art. 57. If the working of the pits is to be in the open air, the owner must, before commencing work, make a declaration to that effect to the Prefect. The Prefect gives an official certificate of such declaration, and the working proceeds without any other formality.—This arrangement is applicable to iron-ores in seams and lodes, in the case in which, in accordance with Art. 69, they are not concessible. —If the working is to be underground, it can only proceed with the permission of the Prefect. The permit states the special conditions to which the manager must conform.

Art. 58. In the two cases foreseen in the preceding Article, the manager must observe the general or local regulations referring to public safety and health which are binding upon ore-pit managements. Articles 93 to 96 of the present Act apply to offences committed by managers of ore-pits, to the regulations of Art. 57, and to the general and local regulations referred to in the present Article.

Section III. *Pyrites and Aluminous Earths.*

Art. 71. The working of pyrites and aluminous earths will be subjected to the formalities prescribed by Arts. 57 and 58, whether it is carried on by the owners, or by others who have obtained their permission to do so.

Art. 72. If the pits are worked by non-owners, they will have to pay an indemnity to the proprietors, the amount of which shall be settled by agreement or expert arbitration.

VIII.

Section I. *Quarries.*

Art. 81 (*modified by the Act of* 27*th July* 1880). The working of open-air quarries requires a simple declaration made to the Mayor of the Commune, and forwarded to the Prefect. It takes place under supervision of the Government, and must conform to the laws and regulations.—The general regulations shall be replaced by regulations made in the form of State Council decrees, in departments where these are in force.

Art. 82 (*modified by the Act of* 27*th July* 1880). When the workings are carried on in subterranean galleries they are under the supervision of the mining administration as foreseen in Arts. 47, 48, and 50.—In Paris the working of underground quarries of any kind is forbidden.—The two decrees, with force of law, dated 22nd March and 4th July 1813, and the decree of general regulation dated the 22nd March 1813, relating to the working of quarries in the departments of Seine and Seine-et-Oise, are repealed.

Art. 83. Peat can only be worked by the owner of the land, or with his consent.

Art. 84. A proprietor who wishes to work the peat-beds on his land cannot do so, under penalty of 100 francs, unless he has previously made declaration at the sub-prefecture and received a permit.

Art. 85. A Government regulation will fix the direction of the works of extraction in the land where the peat is situated, that of the drying-trenches, and in fact all the measures for facilitating the flow of water in the valley, and the deposit of the peat cuttings.

Art. 86. The owners working the peat, whether private individuals, commonalties, or public institutions, must conform to the above under penalty of being obliged to cease working.

IX. Of Expert Arbitration.

Art. 87. In all cases foreseen by the present law, and in other cases arising from special circumstances in which expert arbitration is necessary, the regulations of Cap. 14 of the Code of civil procedure, Arts. 303 and 323, shall be carried out.

Art. 88. The experts shall be chosen from among mining engineers, or men eminent and experienced in mining matters.

Art. 89. The Imperial Procurator shall always be heard, and shall give his opinion on the reports of the experts.

Art. 90. No plans shall be admitted as evidence in a contested case, unless submitted or approved by a mining engineer. The verification of plans shall always be made gratis.

Art. 91. The expenses and fees of experts shall be assessed and fixed, according to circumstances, by the courts; also the honoraria of mining engineers; all being in accordance with the scale fixed by a Government regulation. Nevertheless, there shall be no honoraria for mining engineers when the operations have been conducted either in the Government interests or in consequence of police supervision.

Art. 92. The deposit of the sums considered necessary for paying the expenses of expert evidence may be required by the court from the party who seeks such evidence.

The Act of 21st April 1810, from which we have given extracts referring to the industry we are discussing, was completed by the *Act of 27th April 1838, relating to the draining and working of mines*, which, when several mines situated in different concessions are attacked or threatened by a common inundation which is likely to imperil their existence, public safety, or the needs of consumers, gives the Government power to oblige the grantees of those mines to carry out, jointly and at their own expense, the works necessary either for draining the whole or part of the flooded mines or to check the progress of the inundation. As this Act has only a limited interest, we think we may forbear from printing the text of it here.

CHAPTER II.

Preparation of Clays.

The preparation which clays must undergo with a view to their use in pottery depends upon their nature, the process of manufacture, and the kind of article to be made from them. We shall only give here a few general remarks, as we intend later on to refer in a more detailed manner to this preliminary work, when we speak of the manufacture of the various products.

We have said that the preparation which clays have to undergo depends upon their properties and the process of manufacture. If, for instance, brick-earth (lehm) is used for what are called native bricks, it is an exceptional case; all other products are usually made of mixtures of different clays or even of foreign substances which have to be incorporated in them to make a homogeneous whole. The physical nature of clays enters into the choice of mixtures; rich clays must be thinned by the addition of antiplastic or thinning bodies, — sand, thin clays, cinders, etc., — while, on the other hand, thin clays must, for certain products, be enriched by loams, etc.

In fact, with the exception of the above-mentioned case, clays coming from the pit require to be treated, in order to remove the hard portions and foreign matter contained in them. Besides this, they have to be mixed with water uniformly, and the whole must be well mixed to form a sufficiently homogeneous paste, well fitted for moulding, drying, firing, and consequently for making good products.

Dry clays also are treated by reducing them to dust in order to mix them with others, or even to use them as they are by compressing them under powerful pressure followed by firing at a high temperature.

These various operations may be summarised under two heads—

1. Disintegration and division of the mass by cutting and crushing; separation of the hard bodies or their crushed remains so that they may mix with the rest of the clay.

2. Addition of foreign substances necessary for the formation of paste, water and antiplastics if necessary; and making a close mixture by pugging or blending. The processes by which these results are obtained are—

Disintegration and division of the mass .	Weathering and decomposition.	
	Cutting	by hand.
		by machine.
	Washing and removal of stones.	
	Crushing and pulverising.	
Addition of foreign substances.—Pugging	Soaking and moistening.	
	Thinning, and treatment with antiplastics.	
	Pugging	by hand.
		by machine.

WEATHERING.

In order to disintegrate the clay after it comes from the pit, it has been customary for ages to extract it in the autumn and to spread it in heaps of various heights on a flat surface. If there are several kinds of clay, they are placed in alternate heaps, so as to make a mixture when the heaps are demolished.

Winter and its climatic changes—rain, snow, frost, thaw—cause a physical alteration which breaks the hard pieces and splits up the mass throughout all its thickness.

Weathering, always a costly operation, has almost entirely disappeared with the introduction of machinery, except for manufacture by the Walloon method, and even for that it has been abandoned in many works.

Decomposition.—Certain plastic clays experience, besides the disintegration caused by winter changes, another phenomenon called decomposition. These clays take a grey then a black colour, setting free sulphuretted hydrogen. On contact with the air the black colour disappears, carbonic acid is given out, and

sulphate of iron is formed. The presence of organic matter appears to be one of the causes of decomposition, for it can be hastened by sprinkling the clay with liquid manure, marsh water, etc.

This special phenomenon gives rise, in the midst of the mass of clay, to complex chemical reactions which last for several years. It is then quite different from what is called weathering.

And besides, it is independent of weather changes, since it can take place in a covered space, provided the clay is kept constantly damp. Water and certain substances are thus indispensable for the decomposition of clays, and so is time. Also, experience seems to show that the oldest pastes are the best. The decomposition of clay is peculiar to the porcelain manufacture, and even for that purpose many important factories have abandoned the process, so we will not lay stress upon it.

We will bear in mind only that decomposition and weathering are different processes, and that both of them, although they have useful effects on the physical qualities of the clay, are being more and more neglected under new economical conditions.

MIXING.

Hand-mixing.—This is done to reduce to shavings the vegetable mould (lehm or limon) used for the manufacture of so-called native bricks. The earth is scraped vertically with the round knife of which we have spoken, and which the workman holds by two handles, one in each hand. Layers of about 60 to 80 centimetres high are taken in turn; the earth falls to the foot of the bed, splitting up and becoming sufficiently granulated to be put as it is into the press-moulds.

Machine-mixing.—This process is applied to non-calculous loams which are treated as they come fresh from the pit. As they are compact and in large lumps which cannot be crushed between cylinders, they are cut up into small pieces which absorb water more easily. For this purpose special machines called *mixing mills* are used, the principle of which is the same as that of chaff-cutters; rotating steel knives meet the motionless

mass of clay and cut it into regular shavings. Cylindrical and conical mixing mills are manufactured.

Cylindrical Mixing Mill.—This consists of a cast-iron framework in the middle of which is a cylindrical pan with movable bottom. The base is a cast-iron plate pierced with oblong holes in the direction of the radii. Each of these openings is furnished with a steel blade which acts as a knife and is fixed with bolts to the plate and projects from it. The plate is fixed to the end of

Fig. 19.—Mixing Mill with Horizontal Tray (Pinette).

a strong shaft which is moved by bevelled gear. The pan is divided into two parts by bars or by a plate fixed against its sides (Fig. 19).

When the machine is set in motion, the plate with the knives begins to turn with a speed of 60 to 70 revolutions a minute. The clay is introduced into the pan, and, the fixed bars preventing it from following the rotation of the plate, the steel blades cut it below. The slices so formed pass through the openings between the blades and the plate and fall to the ground, their size being greater or less according to the dimensions of these holes.

The machine is strong enough to stand shocks caused by little stones being broken by the knives. If the stone is too large the driving-belt slips, and the machine must be thrown out of gear in order that the stone may be taken out by the hand.

The yield of a mixing mill depends upon the amount of moisture in the clay and the size of the machine.

Conical Mixing Mill (Fig. 20).—The principle is the same

Fig. 20.—Conical Mixing Mill (Lacroix).

in this, but the knives are fixed on the surface of the frustum of a cone. The clay, being thrown into the frustum, is kept motionless by a fixed partition as in the flat-bottomed machine.

Usually the mills are placed immediately above the soaking-trenches (Fig. 21). It is easy to so arrange the machine that it shall supply several trenches by placing it at a certain height, and guiding the clay into the more distant ditches by means of inclined planes kept damp by a slight stream of water.

Sometimes an endless band is placed under the mill, as in Fig. 19.

SEPARATION OF FOREIGN SUBSTANCES.

It is preferable, for many reasons, not to use clays which contain too much foreign matter,—stones, sands, pyrites, etc.,—but there are cases in which one cannot do otherwise, and then the foreign substances have to be removed.

Cleaning by hand is only suitable for expensive clays like

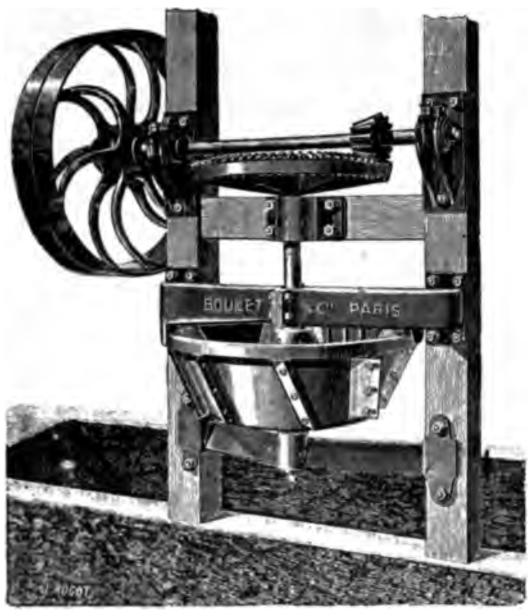


Fig. 21.—Conical Mixing Mill (Boulet).

the kaolins; generally washing is used to remove the sand and gravel, and stone-removing machines for the larger stones.

Washing of Clays.—This is an excellent but a costly process for freeing clays from the heavy products contained in them. It is used with kaolins, and for preparing the fine pastes used in decorative terra-cottas and certain kinds of pottery.

The substances which clays deposit, when washed with water, are pyrites or quartz sands (silicious), with felspar or mica.

The apparatus used depends upon situation and the quantity of water available. In works where both are satisfactory, the process is carried out in large walled ditches, through which a current of water is passed over the clay. When there is a sufficient quantity of water, the clay is stirred up so as to make a kind of clear pulp, while the dense substances remain at the bottom; when all the clay is in a state of pulp, it is passed into

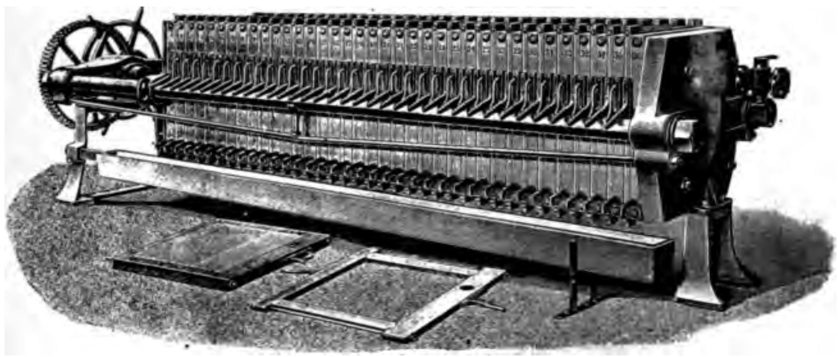


Fig. 22.—Filter Press for Clay (Wegelin and Hübner).

reservoirs, where it falls to the bottom. The remaining water is removed by decantation, and for this purpose the reservoirs are arranged in cascades.

In order to prevent the current of water from carrying with it part of the foreign substances, the pulp may be passed over a kind of filter which retains them. When the deposit, which has been exposed to the air, is firm enough to be handled, it is taken out to be compressed by different methods, the quickest and least cumbrous of which is the filter press (Fig. 22).

The use of deposit-reservoirs necessitates a very large space and considerable cost of installation, when the output is large; therefore it is desirable in certain cases to substitute for them a system of diluting the clay in sheet-iron tanks with sieve bottoms which retain the foreign bodies and let the pulp pass. The latter is forwarded by means of a pump to the filter press. The apparatus is easily moved complete, and sometimes is combined with a motor which works the pump for transferring the pulp to the filter press. This latter contains a certain

number of compartments which communicate with the pipe bringing the pulp under pressure. The water runs off, and when the filter press is full of clay, the entrance tap is turned off and the pulp conducted into another filter. The clay is thus obtained in the form of a paste still containing much water, which is removed by compressing the plates strongly by means of a fly-wheel moved by a central screw. The pump (Fig. 23) has an elastic membrane which separates the piston

Fig. 23. Membrane Pump for Filter Press (Wegelin and Hübner).

from the muddy liquid to be raised. There is therefore no damage from the hard bodies to be feared.

To make the production continuous, it is sufficient to constantly remove the stones. This is done by using a rotating sifting cylinder slightly inclined.

The pulp is prepared in a tub, A, and flows with the foreign substances into a perforated rotating cylinder, C. The pulp falls into a reservoir, D, while the impurities, drawn by the rotatory motion of the cylinder, are poured into the waggon, W, which is

changed when full. The pulp is drawn up by the pump and sent on to the filter press F.

We must not forget that the washing of clays only removes certain impurities such as sands and stones, foreign bodies like limestone, pyrites in an impalpable condition, oxide of iron,

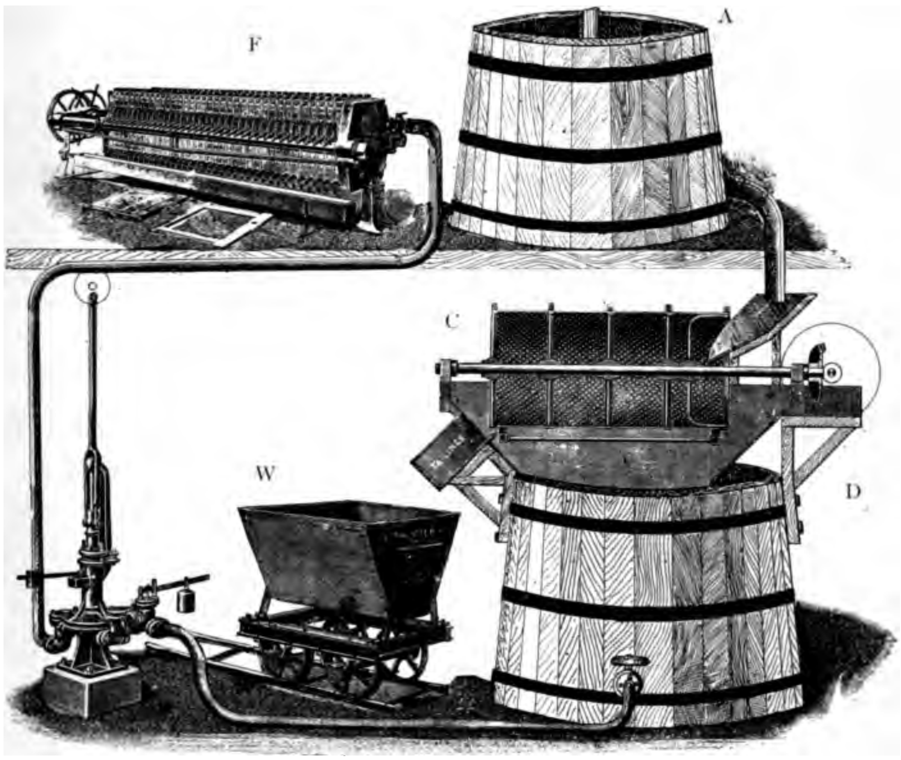


Fig. 24.—Arrangement of an Installation for continuous Washing of the Clay.

etc., becoming shaken up with the clay and remaining in suspension with it.

Mechanical Stone-removing.—This process is not as perfect as the foregoing, but it allows of the expulsion of stones or other hard bodies of a certain size. The apparatus used is composed of two conical rollers placed according to their generating lines (Fig. 25), and moved by a conical gear. The machine is fed without interruption like the other rolling-machines. The foreign substances advance automatically and are expelled by a gutter which may be seen on

the left of the figure. The clay afterward passes between the rollers and undergoes a first flattening. The machines made by Messrs. Jäger (Fig. 25) treat in 10 hours a quantity varying

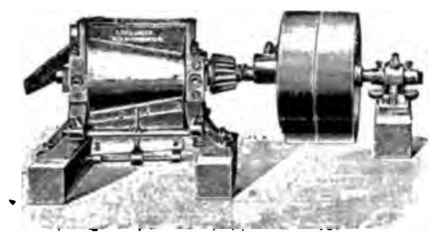


Fig. 25.—Stone-removing and Rolling Machines (Jäger).

according to their size, from 10,000 to 70,000 bricks, and require from 3 to 7 horse-power. Their weight varies from 1500 to 4000 kilos ($1\frac{1}{2}$ to 4 tons).

Another machine of the same kind is shown in Fig. 26.

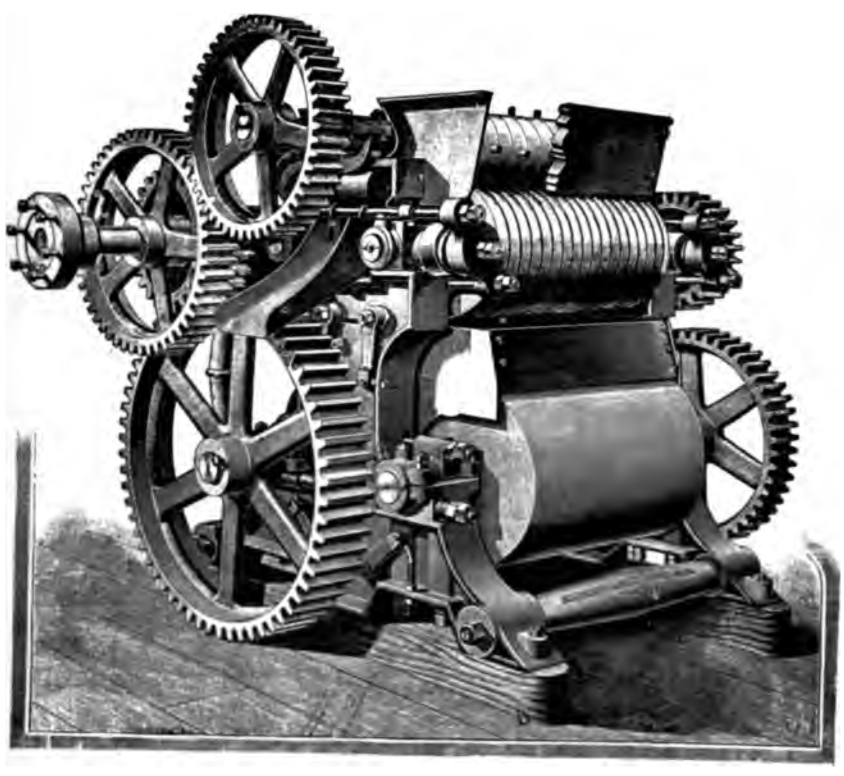


Fig. 26.—Stone-removing Machine (Penfield).

CRUSHING AND PULVERISING.

Crushing.—This is done, in fresh clays, in order to destroy hard lumps and to crush the foreign substances contained in them: limestone, schists, quartz, flint, etc. Dividing and crushing cylinders are used.

Dry crushing is used with dry clays which are reduced to powder, either for use as they are or for mixture with others. Finally, substances are crushed for use as antiplastics, such as sands, slag, fragments of pottery, etc.

Damp Crushing.—*Dividing Cylinders.*—When the clays are too hard or in pieces difficult to treat with the mixing mills, special cylinders are used to split them up. Some carry tempered steel points (Fig. 27) to catch the large pieces of clay which

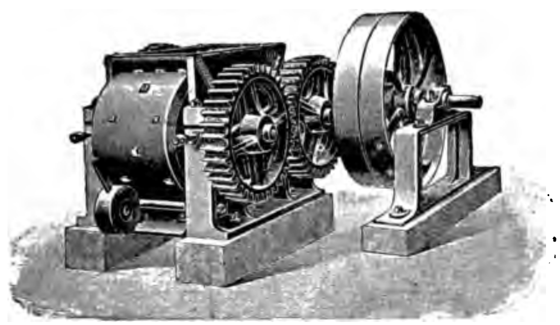


Fig. 27.—Crusher and Divider with Interchangeable Points (Jäger).

might slip over smooth cylinders. The fragments of clay thus obtained are sent on for rolling or soaking.

In the machine shown in Fig. 28, the diameter of the cylinders plays the same part as the steel points of the foregoing machine. This machine, which is very strong, is supplied direct from waggons, and the large pieces or unseparated parts of the clay are reduced to the size required for a satisfactory soaking.

Crushing Cylinders.—These are used to crush hard bodies, such as limestone or flint, which may be contained in the clays. They should be very hard, and the whole of the machine

extremely strong in order to resist the violent shocks. Usually two or three pairs of cylinders are placed one over the other, the distance between them decreasing, and the clay falling from one pair to another.

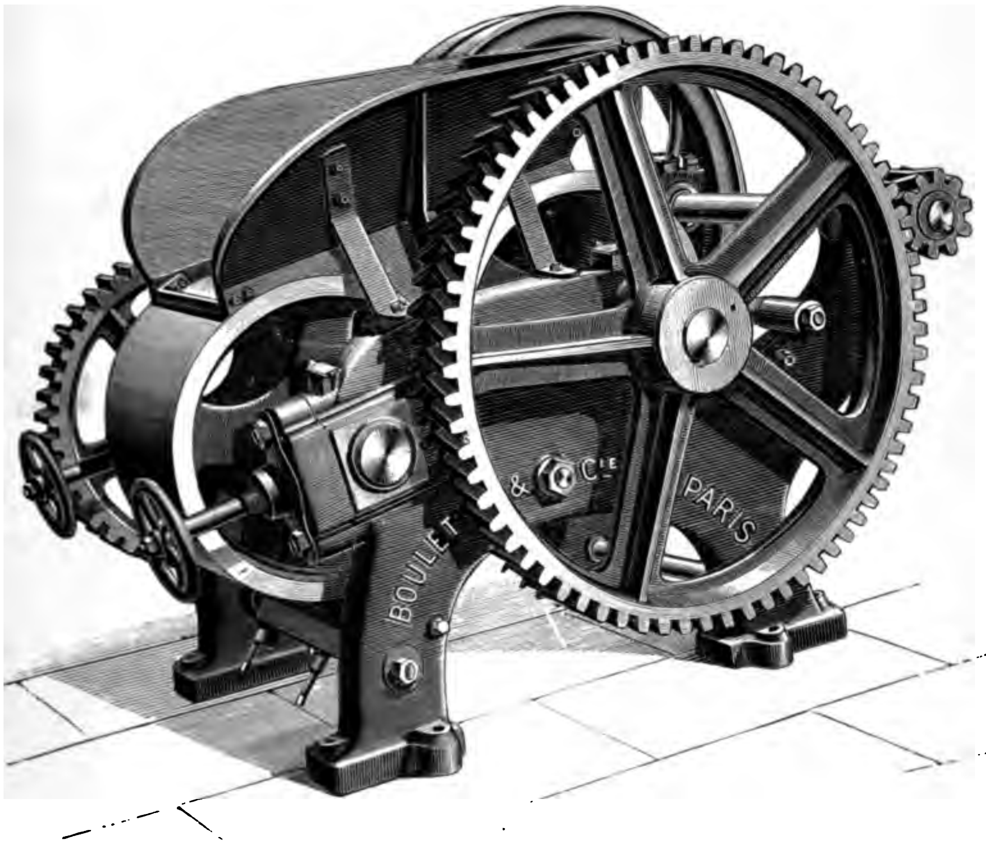


Fig. 28.—Large Dividing Cylinders (Boulet).

The cylinders are smooth or fluted, and their diameter varies from 35 centimetres to 1 metre, the length being always 60 centimetres. The clay is brought to the cylinders by endless bands, or poured in direct from waggons, or thrown in with the shovel.

The cylinders represented in Fig. 29 are also used to crush the clays, but have also this peculiarity, that by the addition of one or two extra pieces of machinery, they can be easily employed for the crushing of dry substances such as fragments

of tiles and pottery; they can thus in a certain measure take the place of the grindstone apparatus generally used for that work.

The extra pieces comprise a lever with counterpoise and an oscillating grating to separate the powder from the large pieces. To increase the effect of this kind of machine, a differential speed is sometimes given to the rollers, so as to add to the crushing action a powerful rubbing. The crushing cylinders

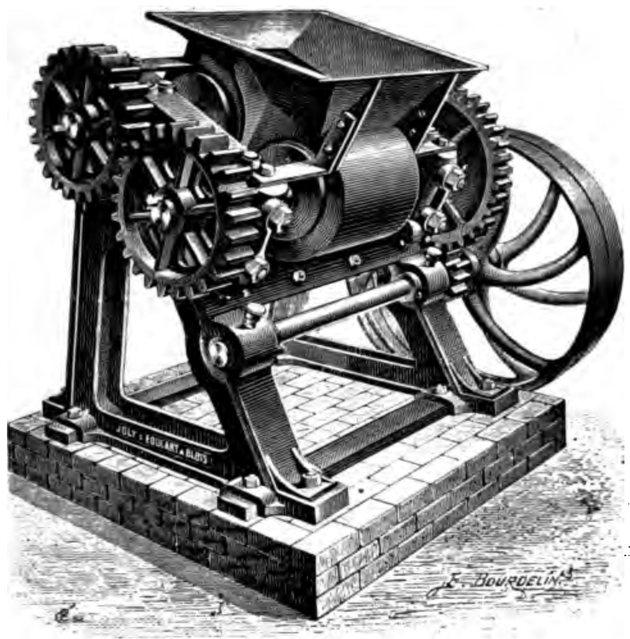


Fig. 29.—Crushing Cylinders (Joly).

of the machine shown in Fig. 30 are arranged in this manner, and so are those of the Whittaker machine (Fig. 31).

As shocks are numerous in these machines, automatic belting is used to avoid breaking the gear-wheels; the movement is transmitted by means of a friction pinion, and a catch which can be put in or out of gear by a lever.

In the foregoing machines the rollers are furnished with scrapers as in flatting-machines, but instead of leaving a layer of clay on the cylinders, these are always kept clean. As the rollers wear out rather quickly, they have to be brought closer

together in order to keep them at the required short distance apart.

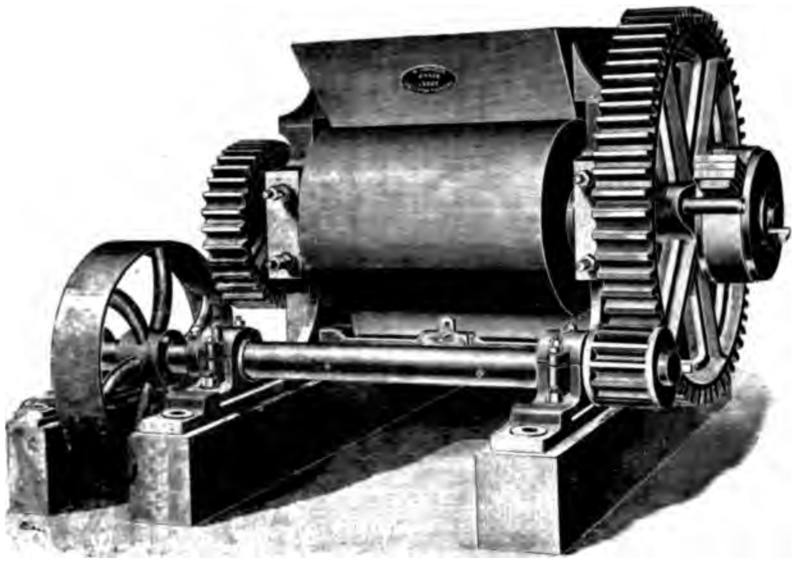


Fig. 30.—Differential Speed Crushing Cylinders (Johnson).

A time comes when the gear-wheels transmitting the motion work deep into one another, in spite of their long cogs, and

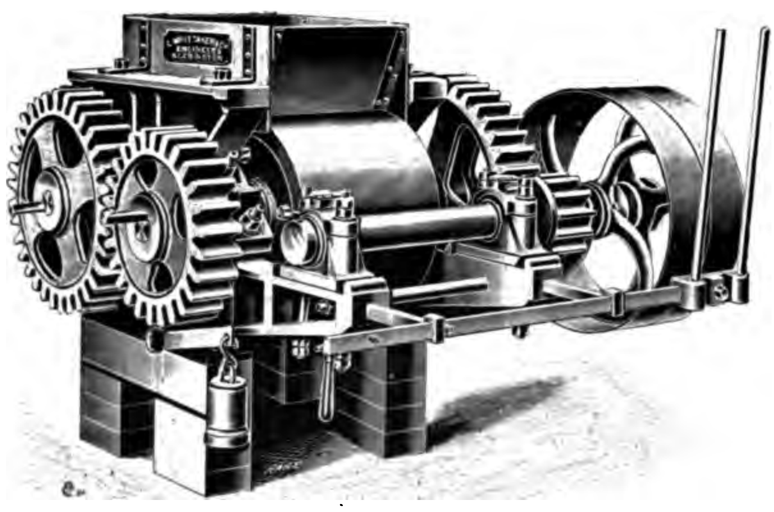


Fig. 31.—Differential Speed Crushing Cylinders (Whittaker).

this will infallibly cause their fracture. To avoid this accident, then, we must have an extra wheel of the same speed but less diameter and substitute it in good time. The one removed is

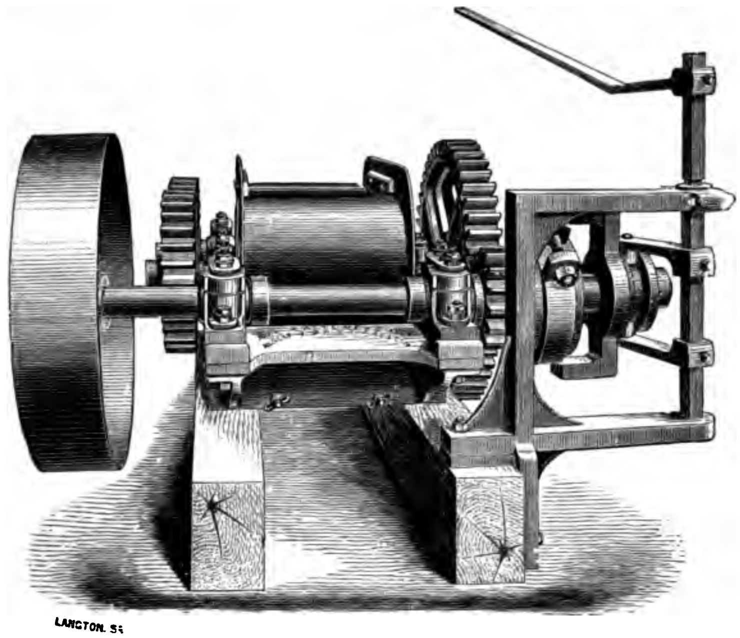


Fig. 32.—Crushing Cylinders with Arrangement for Throwing Out of Gear (Whitehead).

not useless, for it will serve again when the worn-out rollers are replaced by new ones.

Dry Crushing.—This process is used in certain cases when the clays are dried, and also to pulverise bodies for use as anti-plastics.

Drying of Clays.—The manufacture of pottery with dry clay only flourishes in warm countries where the extreme dryness permits of easy desiccation of the earths. In other climates the cost of drying prevents a general use of this method. Nevertheless certain clays are worked in a dry state by leaving them for a long time in the air under covered sheds.

For artificial drying, large hot-air ovens are used; the clay is placed in layers of 15 or 20 centimetres thick, and moved from time to time. For large works, continuous kilns are used. The clay is thrown into an upper hopper, and thence falls into

the oven itself, which is heated by coke furnaces giving a moderate heat to a large extent of air. This air, loaded with water vapour, issues by means of openings made in the arch supporting the hopper, and passes into two longitudinal conduits, whence it goes into a chimney. A kiln 7 metres high, 2 broad, and 4 long dries in 24 hours about 15 cubic metres of clay containing 13 per cent. of water, and uses 400 to 500 kilos of coke.

Pulverisation.—This is done by grindstone mills in the case of clays and in general for substances of medium hardness. In the case of very hard and bulky substances, it is advisable to use pounding mills and special crushers.

Crushing Mills.—These consist of vertical grindstones of varying weight, and circular cast-iron pans into which the substances to be crushed are placed. Sometimes these pans are fixed, sometimes they are movable. The separation of the pulverised portions from the coarser ones is effected in several ways: either by a central inclined sieve, on to which an automatic feeder throws the substance; or by the bottom of the pan itself being perforated with a number of holes, whose size depends upon the coarseness of the powder to be produced.

Crushing Mills with Central Sieve and Automatic Feeder.—The pan is of cast-iron and has in the middle a hollow covered by a sloping sieve, the fineness of which varies with that of the product required. The vertical shaft which works the grindstone carries with it a chain of buckets supported by a shaft perpendicular to the first one, and rotated by means of a bevelled gear as shown in Fig. 33. The buckets pick up the pulverised matter into a wooden gutter which guides it on to the sieve; the portions which are too large to pass it fall back again into the pan, and the powder is received into a lower receptacle, whence it is removed by various means according to the locality.

If it has to be carried to a higher level, a kind of shaker is used, moved by a belt, and constructed to throw the pulverised substance into a trough from which it is carried by a bucket-chain to the required height.

The apparatus here represented may have two grindstones instead of one. The weight of these stones varies according to

their size from 350 to 3500 kilos (6 cwt. to over 3 tons), and as they are hollow, this weight is increased by bricking them inside. Thus a simple grindstone like that in Fig. 33 weighs 350 kilos; filled with bricks like that in Fig. 34, it weighs as

Fig. 33.—Crushing Mill with Central Sieve and Automatic Feeder (Jannot).

Fig. 34.—Crushing Mill (Luce).

much as 850 kilos. The crushing mill of Fig 34 differs very little from the preceding one.

Crushing Mills with Perforated Pans.—These may either have fixed or movable pans. The one in Fig. 35 has a fixed

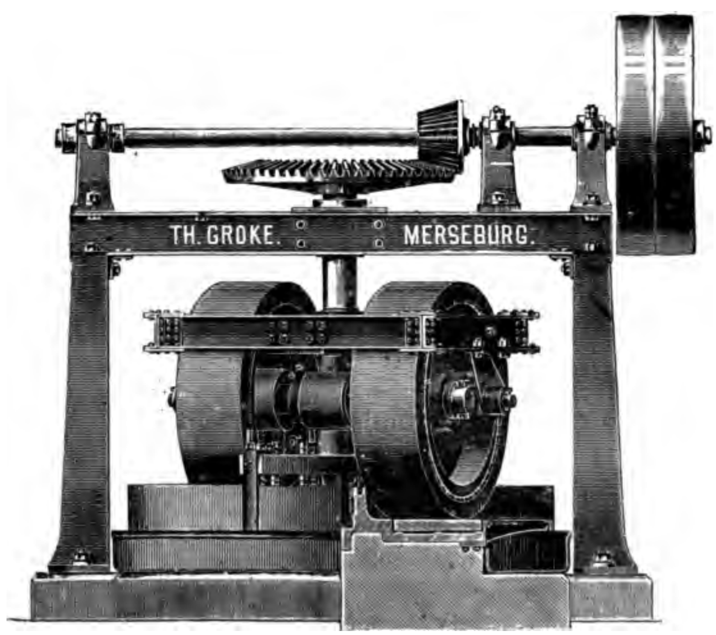


Fig. 35.—Crushing Mill with Fixed Pan (Groke).

pan pierced with a series of holes; the grindstones set in motion by the bevelled gear crush by their weight and speed the substance to be pulverised. The powder is collected in a closed space, whence it can be raised by a bucket-chain to be distributed, if required, to other machines. In other mills the pan is

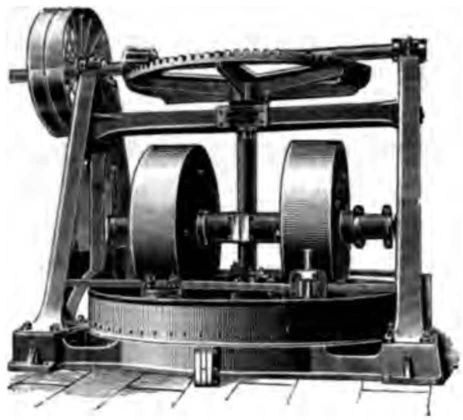


Fig. 36.—Crushing Mill with Movable Pan (Johnson).

movable and the grindstone is fixed on an axis which is held between slides and so can be raised or lowered. The grinders thus follow the level of the substance to be crushed, and turn round on their axis in consequence of the friction caused by the pulverisation.

The arrangement of the pans naturally depends upon the makers. Figs. 37 and 38 show us the different arrangements. In the machines represented the motion of the pan is transmitted from above by means of a vertical shaft which passes through, but with slight friction, the axis of the two grindstones. On the other hand, in the mill represented in Fig. 39 the pan carries a cog-wheel, and the motion is transmitted below.

The perforated bottom of the pans is made up of several segments which can easily be replaced when worn out, the parts being interchangeable.

A special crushing mill, represented in Fig. 40, is used to reduce agglomerated sand to powder. The peculiar shape of

the grindstones or rather of the fluted cylinders allows of easy crushing of the lumps.

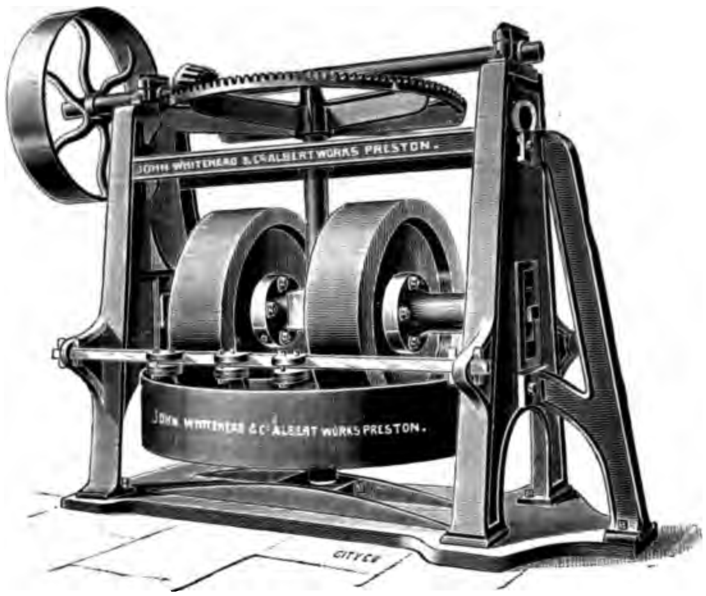


Fig. 37.—Crushing Mill with Movable Pan (Whitehead).

Universal Pounder and Crusher.—These are used to reduce hard bodies to small fragments. They are composed (Fig. 41)

Fig. 38.—Crushing Mill with Movable Pan (Whittaker).

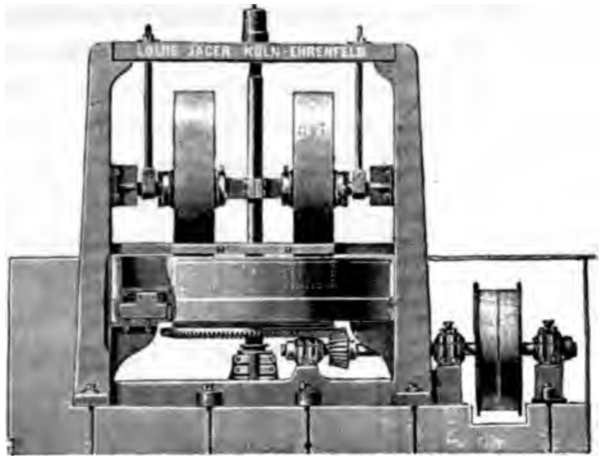


Fig. 39.—Crushing Mill with Movable Pan (Jäger).

Fig. 40.—Crushing Mill for Sand (Luce).

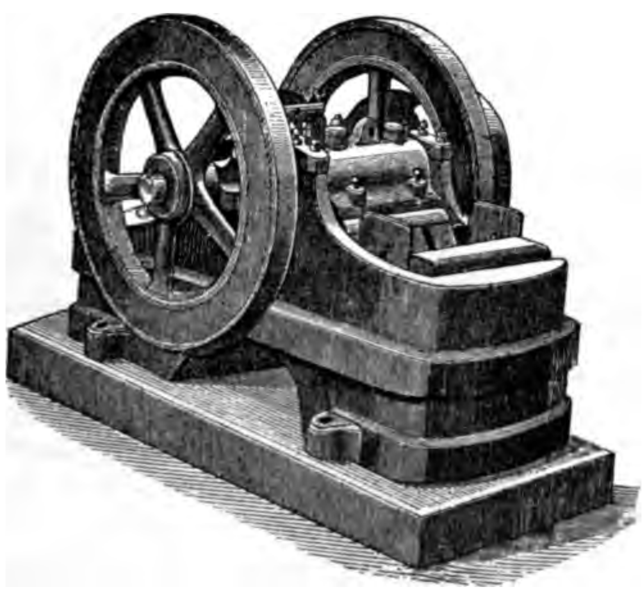


Fig. 41.—Pounder for Hard Bodies (Börner).

of movable cheeks between which the material is broken and reduced to larger or smaller fragments according to the distance between the cheeks. These regular fragments are afterwards passed under the wheels of mills to reduce them to powder.

Another machine used to crush these bodies direct is Carr's universal crusher. It is composed of a certain number of

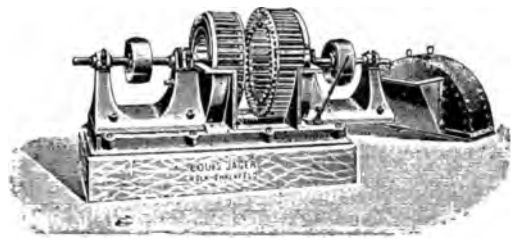


Fig. 42.—Carr Universal Crusher—the Cages separated (Jäger).

concentric barred cages fixed upon a rotating plate. Other cages, also concentric and of diameter intermediate to the preceding ones, are fixed to another plate which revolves in the opposite direction. This second plate and its shaft are mounted on a support which can slide longitudinally, so that the cages fit one within the other (Fig. 43).

When the machine is working, the cages being thus fitted together, two contrary movements are produced. The whole

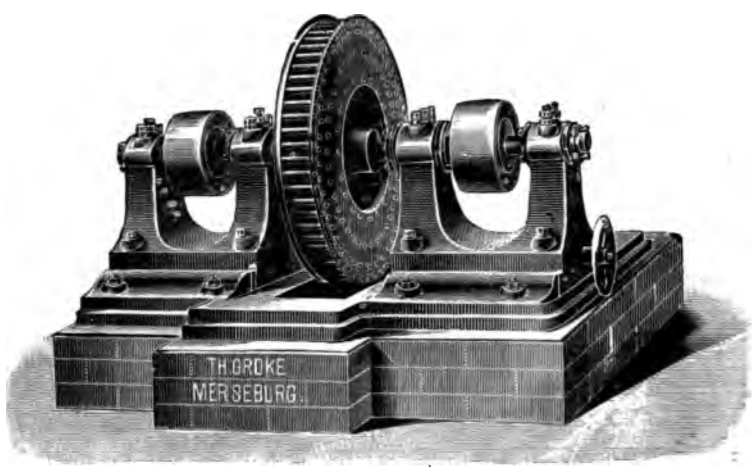


Fig. 43.—Carr Universal Crusher—the Cages together (Groke).

is contained in a sheet-iron cover, shown on the right of the sketch, and the substances to be crushed are thrown in by the hopper fixed to it. They receive a shock against the bars of the first cage, and after passing through those bars, meet those of the second cage, which are turning in the opposite direction, then those of the third, and finally those of the fourth, each being opposite in direction to the preceding. At last they fall outside in the form of a powder the fineness of which depends upon the number of turns of the cages. These latter, rotating within the cover, act as ventilators, and prevent dust in the workshop.

The production of this machine is much greater than that of any other used for the same object, but it requires a considerable motive power.

ADDITION OF WATER TO CLAYS.

Clays coming from the pit very rarely contain enough water to be worked as they are, especially in summer; it is necessary to moisten them. This operation is called *soaking* or *moistening* according as the clay is rich or thin.

Moistening.—Moistening differs from soaking in this: thin clays absorbing water much more easily than rich ones, do not require to be placed under the water; it is sufficient to sprinkle them when they come from the pit, and leave them to absorb the moisture uniformly, or to accelerate the equal partition of it by mechanical means. Moistening is also suitable for powdered earths which have to be damped in order to be transformed into ceramic products.

The moistening of clays requires much attention, for on it depends their satisfactory manufacture. The amount of moisture which a clay should contain depends upon its nature; nevertheless, we must not forget that, in the mechanical part of manufacture, if the clay is too damp the products lose shape and cannot be handled; if, on the other hand, the clay is not sufficiently damped, the products do not hold together, and fall to pieces. We must then choose a suitable intermediate state so as to get

a fairly firm paste resisting manipulation and at the same time giving the maximum production, for the power used in working increases with the hardness of the clay. There is then a happy mean to be found, which only experience can indicate.

The uniformity of damping has of course no less importance than its amount; if there are in the clay some parts softer than others, the products will be defective.

To attain good results, the clay coming from the pit is spread, after being reduced to small fragments by some process or other, in a thin layer, then damped more or less according to the natural moisture it contains, which varies with the season and weather. Another layer will then be spread over the first, and if clays of different nature are used, they will be placed alternately, each layer being sprinkled in turn. The clays will now be left for at least twenty-four hours to become uniformly damped. A longer period will not be injurious if the surface is prevented by a covering from getting dry.

In order to work it, the heap will be cut vertically, so as to make a first mixture of the different layers. The clay will be placed in a pug-mill, either with a shovel, if the heap is near the machine, or by an endless band if it is far off, or by any other means. The clay may be laid in ditches, instead of on the earth.

Moistening Machines.—The uniform moistening of the clay is effected by means of special machines, the object of which is to cause a complete mixture of the clay with water. These machines are especially useful in the case of powdered earths, but they can also be used for clay from the pit. They consist principally of a cast-iron or sheet-iron trough, in which is a shaft furnished with curved pallets or mixing blades according to the clay to be worked, and moved by a belt-wheel.

Above the trough is placed a pipe pierced with holes through which the water falls on to the clay while it is being stirred by the knives (Fig. 44).

These knives, something like screw - propellers, cause a motion of translation which carries the clay from the front of

the machine, where it is introduced, to the back while mixing it closely with the water.

The discharge is effected either direct on to the ground (Fig. 45) or through an aperture in the lower part of the trough

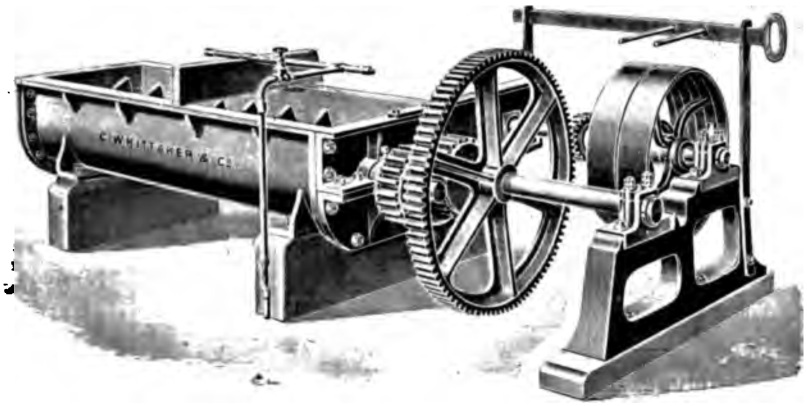


Fig. 44.—Moistening Machine (Whittaker).

(Fig. 44) or in the vertical wall. The clay, thus uniformly moistened, is afterwards transferred to other machines for working.

The belt-wheel of the machine is either placed in a separate frame, as in Figs. 45 and 46, or fixed directly on to that of the machine, as in Fig. 47.

Fig. 45.—Moistening Machine (Groke).

The transmission of motion is effected by conical and cylindrical gear-wheels.

Instead of a single shaft there may be two turning in opposite directions. A machine of this kind is shown in Fig. 48.

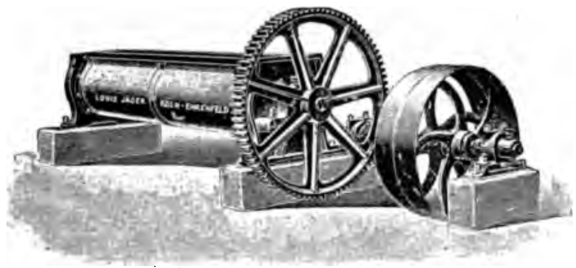


Fig. 46.—Moistening Machine (Jäger).

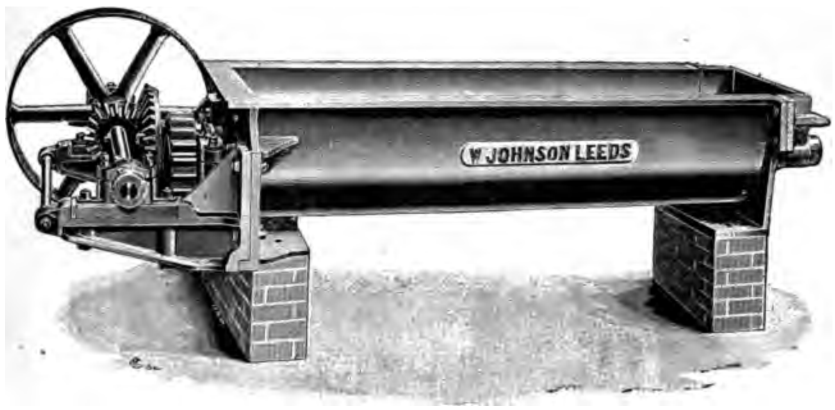


Fig. 47.—Moistening Machine (W. Johnson).

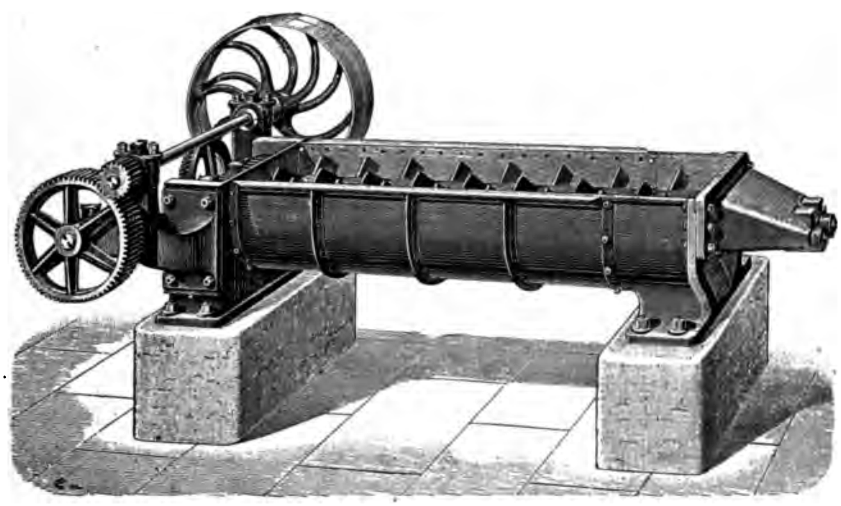


Fig. 48.—Moistening Machine (Boulet).

When the machines are constructed to moisten powdered substances, the useless knives are replaced by curved pallets which stir the powder better and facilitate the incorporation of the water.

Moistening and Crushing Machines Combined.—When the clays have to be crushed before damping, instead of having two machines they are combined in one. All that is required is to arrange the framework of the moistening machine to receive crushing cylinders as we see in Fig. 49.

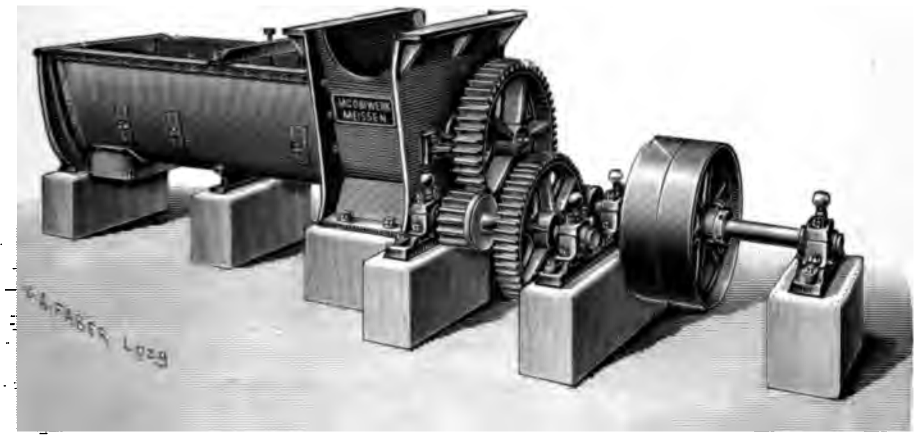


Fig. 49.—Moistening Machine with Supports to receive Cylinders (Jacobi).

The cylinders may be conical or cylindrical, and two or four in number, as required. The machine represented in Fig. 50 has a pair of spiked crushers and another pair of conical rollers.

The machine in Fig. 51, called damping trough, is also provided with flatting friction cylinders to which is attached an automatic distributing tray.

In the trough are arranged two horizontal shafts furnished with screws crossing one another in their motion. The water is thrown on the clay by means of percolators.

Soaking. Rich clays are damped with difficulty. Simple moistening as used for thin clays is not sufficient to damp them enough for working; a long stay in water is required in ditches as water-tight as possible.

This process, called soaking, is carried out after cutting or crushing, but before blending with shortening substances. Generally the ditches are situated below the cutting or crushing machines; when they are at some distance the clay must be carried to them by means of inclined planes or endless bands.

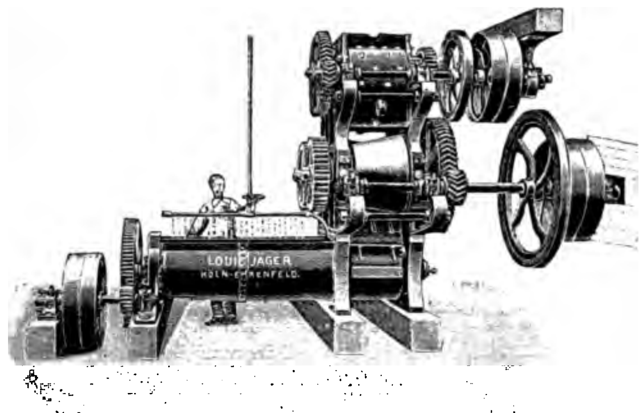


Fig. 50.—Moistening Machine fitted with Crushing Cylinders (Jäger).

The size of the ditches depends upon the importance of the factory and the manner in which it is arranged.

In some cases, their capacity is as much as 20 or 30 cubic metres; the depth of the clay in the ditches is as much as 1 to $2\frac{1}{2}$ metres, not more. As twenty-four hours are required for uniform

Fig. 51.—Moistening Machine (Damp Trough) fitted with Rolling Cylinders (Lobin).

and complete soaking, it is arranged that the total volume of the ditches should represent double the daily consumption of clay. To avoid waste of time the ditches are sometimes made with removable ends, so that, if one end is removed, it is only necessary to cut the mass, and put the clay into the pug-mill close by,

mixing it with antiplastics which are also placed near at hand. This being so, only just enough water should be added to give the paste a sufficient consistency without making it too soft. When the local conditions and the nature of the clay are favourable, this is undoubtedly an economical arrangement.

In other manufactories the clay is submerged for twelve or twenty-four hours, and then the water is drawn off; the clay is then taken from the ditches and placed on slightly sloping ground in thin layers between which is put the necessary quantity of thinning matter. When the heap reaches a certain height, it is drained until it reaches the required degree of dampness, then it is cut in vertical slices and put either into the pug-mill or straight into the hopper of a machine. Finally, in other factories the clay, or clays if there are mixtures, and the thinning substances are put together for damping.

Soaking is equally important for rich clays as for thin ones, therefore it must be watched with great care; on it depends successful manufacture.

SHORTENING.

Rich clays cannot be used alone on account of their eminently plastic properties. They stick too much to the moulds or cylinders of machines, and the paste they form with water falls in and loses shape after working. Its very tenacity prevents equal drying in all parts of the mass, hence cracks are formed going from the drier surface to the damper interior. If the pieces have parts of different dimensions, the less thick parts dry more quickly than the thinner ones, causing deformations. Firing increases these faults still more.

The only way to avoid these accidents is to mix closely with the rich clays, substances which will thin them sufficiently to be easily worked, uniformly dried, and satisfactorily baked. These substances are called antiplastics, shortening, or thinning materials.

Antiplastics.—Their function is to diminish the plasticity of rich clays. When mixed closely with the latter, they form within the mass a kind of skeleton which has two uses: to

support the plastic paste and prevent it from losing shape, and afterwards to assist drying by acting as a system of drainage. Thus unequal drying and warping are avoided, for the anti-plastic skeleton is so identified with the clay that it follows its contraction and maintains the regular shape of the piece.

Natural Antiplastics.—First of these substances is *sand*, which is an excellent shortening matter. According to its nature it will communicate special properties to the paste: if it is silicious (quartz) it will diminish the fusibility of fusible clays; it will, on the contrary, increase it if of a felspar, iron, or limestone nature. If the sand contains large grains, it will be passed through a sieve, and if necessary crushed.

The pulverisation of sandstone gives a sand which may advantageously be substituted for ordinary sand, but which is naturally dearer on account of the cost of pulverisation.

Carbonate of lime and chalk may be used as shorteners, but with great care. In fact, if in firing, the lime formed by decomposition of the limestone does not combine entirely with the silicate of alumina, and in order to attain that object a temperature is required not usually reached in firing, it will be found scattered about in the mass, and by its abundance will make the products fall into powder. In faïence pastes it is used for reasons which we explain on p. 21.

The clay marls, and in general thin clays, are all indicated for shortening potter's clays; the reverse is equally true, and the addition of a certain amount of rich clay to a thin one assists the working of it noticeably. A marl clay should not contain more than 10 to 20 per cent. of limestone to be used direct, but if used as an antiplastic, this proportion may rise to 30 per cent., as long as it does not exceed equal parts in the mixture.

Cinders, Coke Dust.—These substances have a double use; like sand they are excellent antiplastics, but they have this additional advantage, that they burn in firing in the heart of the mass, thus spreading the heat evenly, and economising fuel.

They are most commonly used in the manufacture of bricks and pottery; the products obtained are less dense in consequence

of the numerous hollows contained in them; but if well baked they are not porous, ring well, and have excellent qualities which cause them often to be preferred to other better-looking pieces.

Too large cinders are taken out by the sieve. The coke dust has the same properties as cinders and is used for the same purpose.

Cements.—These are formed from the pulverisation of fragments of bricks, tiles, and pottery, and possess antiplastic properties similar to those of sand. They would be too expensive for use with ordinary products on account of the cost of pulverisation, but they are commonly used in working refractory substances and other ceramic products of fairly high price. Naturally fragments are also used of out-of-date or defective pieces such as bricks, crucibles, glassware, retorts, saggers, etc.

Antiplastics of vegetable origin such as *sawdust*, husks, and straw can only be employed occasionally on account of their high price in our countries. As they disappear in firing and leave large hollows, they are used for objects which require great porosity, like water-coolers, or those intended to resist sudden changes of temperature, like enameller's plates.

Artificial Antiplastics.—*Slags, dross, scoria.*—When pulverised these substances form excellent shorteners; they are, however, less economical than cinders in spite of their lower cost, because their pulverisation is difficult, and they have little or no calorific power. The machines used to pulverise these substances for use as shorteners vary according to their hardness. For some, like sand and cinders, crushing mills such as we have described suffice; but for hard and large bodies like fragments of pottery, Carr machines are necessary.

BLENDING OR PUGGING.

This is one of the most important processes in the manufacture of pottery; its object is to change the clay or mixture of clays and antiplastics into a homogeneous paste without break in continuity. Pugging is done by hand or machines; the former is peculiar to brick-making by the Flemish method. Besides

the ease of working given to clays by pugging, it gives the products a remarkable resistance.

An experiment made by Colonel Gallon of the Engineers shows the influence of this process on resistance.

A brick made with clay once pugged, and another made with the same kind of clay twice pugged, after having been fired under similar conditions were broken under weights of 34 kilos and 64 kilos respectively, applied at the ends, the bricks being placed up on edge and supported in the middle.

Hand-pugging.—Pugging was formerly effected by treading, workmen called treaders trampling on the clay with a sufficient quantity of water in tanks. This primitive process has now been abandoned, except perhaps in the manufacture of certain porcelains.

In the very numerous brickworks where hand-power is used, this is how the pugging is done.

A hoe and a flat wooden shovel (Figs. 52, 53, 54) are the

Fig. 52. Fig. 53.

Fig. 52.—End view of Hoe. Fig. 53.—Side view of Hoe.
Fig. 54.—Wooden Shovel.

tools used. The latter is slightly concave, and is about 40 centimetres high by 25 broad; it is made of a single piece of wood. The workman attacks the heap of clay with the hoe; he brings down and spreads evenly on the ground a certain amount, then sprinkles it with water, and generally scatters cinders over it. Afterwards he lets fall on this layer another which he waters and covers with cinders like the first. He thus prepares two or three cubic metres to a thickness of 40 or 50 centimetres. This heap is cut for the first time with the hoe, the workman pulling the clay towards him so as to disturb it, and more water is

sprinkled on it. The second time the workman beats it with the heel of the hoe; when this beating is completed the shovel comes into use. The workman cuts the heap from top to bottom and throws his shovelful violently to the side to form a new heap. From time to time he dips his shovel in a bucket of water to prevent the clay from sticking to it. This shovelling is followed by another beating; and when these processes have been repeated several times the pugging is complete. The workman arranges his heap in the form of a large round slab, which he smooths over with a well-damped shovel to prevent the surface from getting dry.

Pugging is better performed by two men; one of them brings the water and the cinders while the other beats the clay and cuts it with the hoe. Afterwards one of them throws it with the shovel under the hoe of the beater. If the pugged clay is not used at once it is kept from the sun by straw matting.

This mode of preparing the clay is, as we can see, long and troublesome, and it has been rendered easier by the use of pugging machines, which are the same as those we shall describe under the head of mechanical pugging, except that they are worked by hand or horse power.

Mechanical Pugging.—This is done with special machines called pug-mills, but mills similar to crushing mills and cylinders are also used. Each of these machines produces a special kind of pugging, and one cannot be replaced by another because their effects are different. For clearness' sake we shall subdivide the three classes of pug-mills according to their construction, as follows:—

I. *Grindstone pug-mills.*

II. *Pug-mills with knives.*

- 1. Vertical
  - *A.* With gearing above
    - *a.* Worked by animal power.
    - *b.* Worked by steam power.
  - *B.* With gearing below.
- 2. Horizontal.

III. *Pug-mills with cylinders.*

IV. *Pug-mills with crushing cylinder.*
  - *A.* Vertical.
  - *B.* Horizontal.
  - *C.* With two cylinders.

I. *Grindstone Pug-mills.*

Generally speaking, these resemble grinding mills, except that the pans are not perforated, and that there is no central sieve. This kind of pugging is, we believe, not very extensively practised. The special arrangement in Fig. 40 shows the application of fluted cylinders to this kind of machine.

II. *Pugging with Knives.*

1. **Vertical.**—*A.* WORKED FROM ABOVE.—*a. Moved by animal power.*—As their effect does not differ from that of those worked by steam, we will postpone a description of the inner mechanism till we refer to the latter. The only difference consists in the way in which the shaft is rotated. On the beam is fixed a pole 3 to 4 metres long (Fig. 55), having two vertical shafts at the end.

It is better to substitute for these shafts a semicircular piece of iron movable about an axis passing through the pole; in this way the motion is more free, and the horse feels shocks less (Fig. 56).

The pans of these pug-mills are of sheet-iron (Fig. 55) or of cast-iron (Fig. 56).

Double-pan pug-mills (Fig. 57) are also made, each pan being furnished with a knife-shaft. Their advantage is that they pug rapidly and well, and thus give a large output.

b. Worked by steam.—Like the foregoing, these are essentially formed of a sheet or cast iron pan, in the centre of which moves a shaft fitted with screw-shaped blades to cut the clay (Fig. 58). Upon these blades are fixed steel knives so arranged as to cut the clay again in a direction perpendicular to the first. At the bottom there is a strong blade of 10 or 15 centimetres in height, and shaped like a reclining **S**, the use of which is to facilitate the expulsion of the clay through the orifice in the side of the pan.

The shaft is rotated in such a direction that the blades make the clay descend by pushing it in front of them.

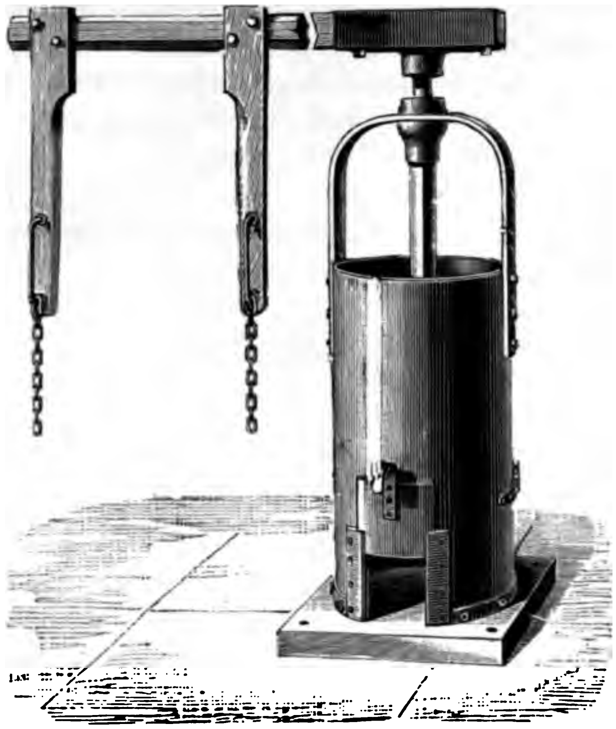


Fig. 55.—Pug-mill worked by a Horse (Boulet).

Fig. 56.—Pug-mill worked by a Horse (Whitehead).

The blades are arranged so as to form a kind of endless screw, hence the clay driven downwards by one blade is taken on by the second before the effect of the first ceases, and its motion is thus continuous. When it reaches the bottom of the machine the ∽-shaped blade expels it by the orifice made for that purpose.

This orifice is provided with a door, the opening of which is

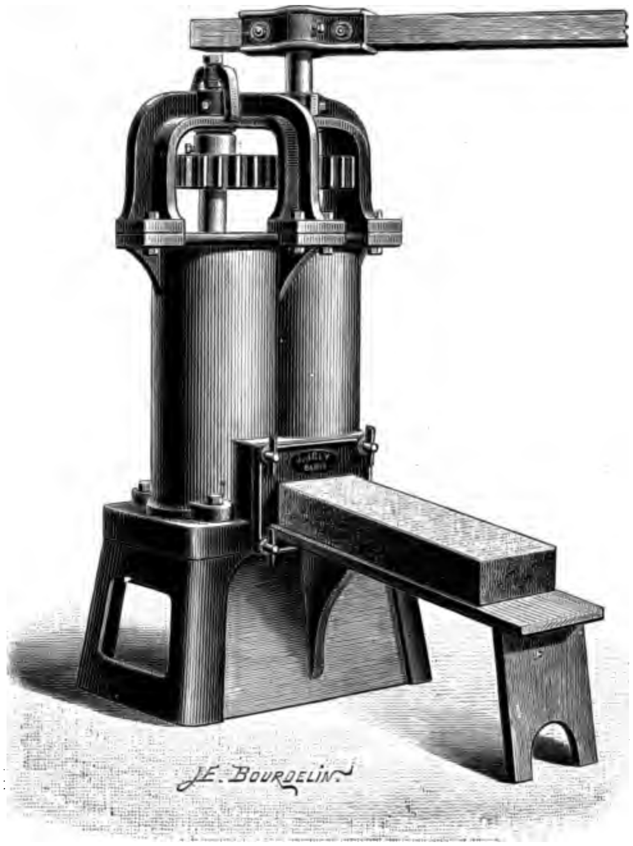


Fig. 57.—Pug-mill with two Pans worked by a Horse (Joly).

regulated at will. Another much larger opening is used for cleaning the interior of the machine; it also is closed with a door.

Sometimes the orifice of issue is placed in the cleaning-door itself, sometimes it is on the opposite side (Fig. 60) or underneath (Fig. 61).

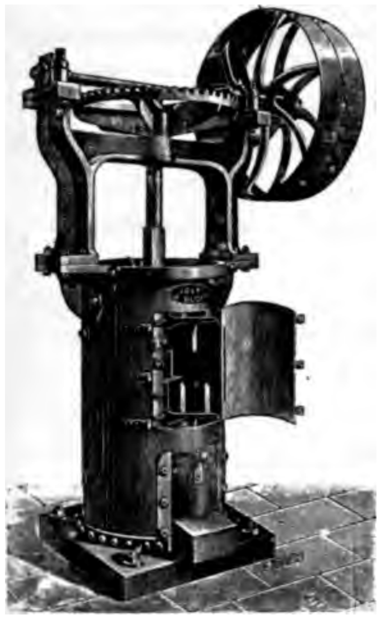


Fig. 58.—Vertical Sheet-iron Pug-mill worked from above (Joly).

Fig. 60.—Vertical Cast-iron Pug-mill worked from above (Joly).

Fig. 61.—Vertical Sheet-iron Pug-mill worked from above (Boulet).

The arrangement of the pug-mills in Fig. 62 is intended to facilitate the introduction of the clay by diminishing the height.

To make the machines lighter the pans are made of sheet-iron instead of cast-iron. But it must not be forgotten that, if we are working with hard paste, the wear is much more rapid in the case of sheet-iron in consequence of its thinness.

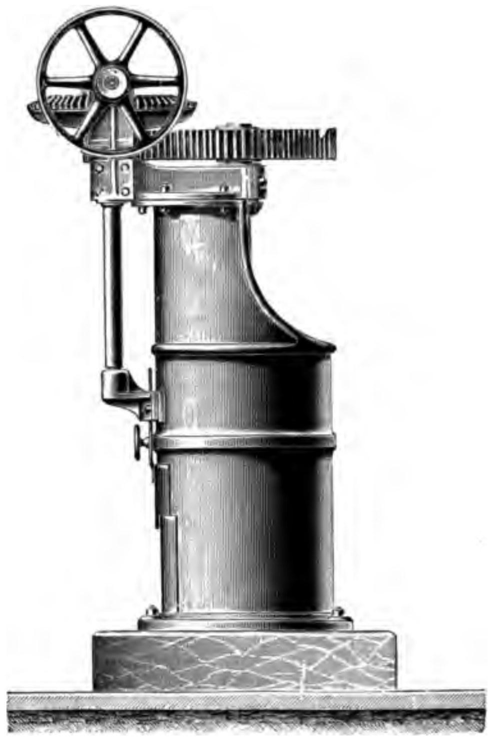


Fig. 62.—Vertical Cast-iron Pug-mill worked from above (Sachsenberg).

The prism of earth expelled from the pug-mill, if it is not immediately cut (Fig. 57), or absorbed by another machine, is driven forward by the clay behind it; but as its weight causes friction on the horizontal surface, there comes a moment when this friction and the pushing of the clay cause equilibrium, the prism advances no further, and the supply from the pug-mill is stopped. This inconvenience must then be prevented by cutting the prism as soon as it attains a certain length. The mode in

which the shaft of the blender is moved varies with the manufacturer; an examination of the figures will show these differences.

B. VERTICAL PUG-MILLS WORKED FROM BELOW.—In certain installations it is sometimes advantageous to use pug-mills worked from beneath. The upper orifice is thus quite free, which facilitates feeding, especially when this orifice can be so placed that the moistened clay can be poured direct into it.

The arrangement of these machines varies with the maker

Fig. 63.—Vertical Cast-iron Pug-mill worked from below (Jäger).

(see Figs. 63, 64, 65). The pug-mill in Fig. 63, however, having its upper orifice completely free, seems to exemplify most thoroughly the advantage of this type of machine, that is to say, ease of feeding.

The Boulet pug-mill (Fig. 65) is specially reserved for the mixing of hard clay, which, owing to the work entailed, requires strong and well-constructed apparatus.

Horizontal Pug-mills.—These are made in different ways, and are used advantageously for clays difficult to mix. The

height of vertical pug-mills cannot exceed a certain limit, while the great length possible with horizontal machines facilitates the

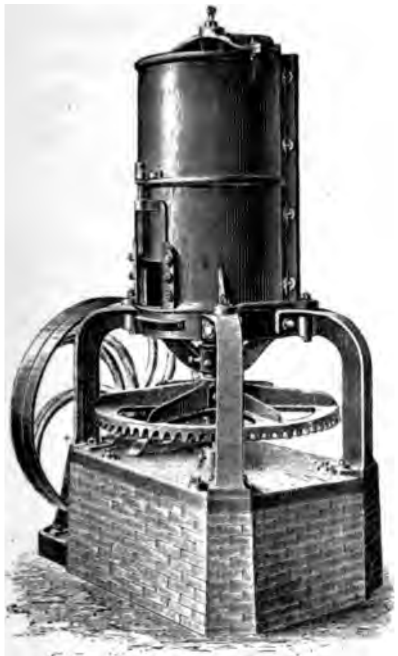


Fig. 64.—Vertical Cast-iron Pug-mill worked from below (Joly).

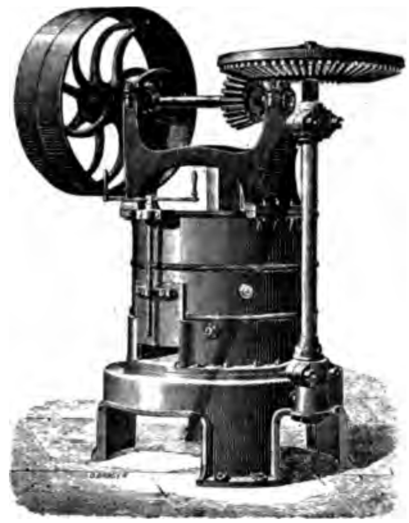


Fig. 65.—Vertical Cast-iron Pug-mill worked from below (Boulet).

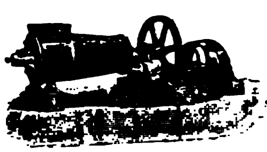


Fig. 66.—Horizontal Pug-mill (Jäger).

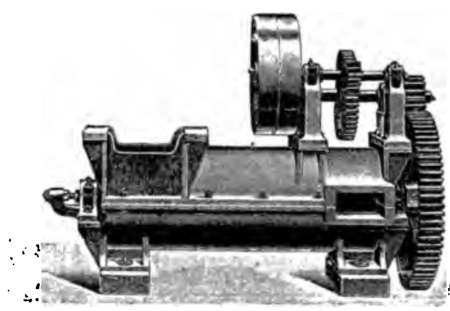


Fig. 67.—Horizontal Pug-mill with attached Gear (Jäger).

incorporation of one clay with another. The introduction of the clay takes place above and the expulsion below (Fig. 66), or on one side (Fig. 67). The gearing is either fixed to the pug-mill or separated from it.

The issue of the clay is regulated as in the vertical machines by a movable door by which the opening may be varied at will; it is held in position by a rod fixed to it (Fig. 68).

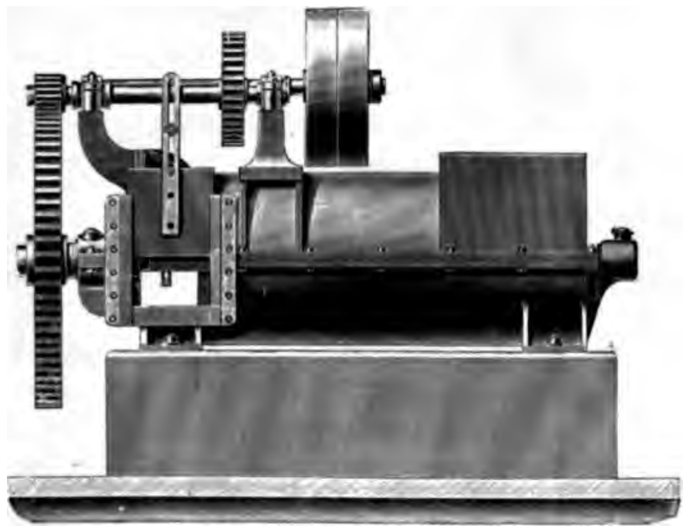


Fig. 68.—Horizontal Pug-mill with attached Gear (Sachsenberg).

III. *Pug-mills with (Flatting) Cylinders.*

We have seen that cylinders are used for crushing the hard bodies contained in clays. For this purpose the cylinders, which are of equal diameter, are fairly distant from one another, and turn with the same velocity. But if different speeds are given to them, or if, while making the same number of turns, their diameters are unequal, the velocities at the circumference will be different and a tearing of the clay will ensue which will effect a mixture. Care is taken to leave between the rollers some clay to the thickness of a few millimetres by placing scrapers to remove the excess. This layer of clay sticks to that contained in the hopper and draws it between the cylinders, where it is united by pressure at the same time as it is being drawn out by the differential speed; this causes a special pugging different in its effects from that produced by the ordinary pug-mills.

Several arrangements are utilised to arrive at the desired result.

1. Use of cylinders with equal diameters and unequal speed, or equal speed and unequal diameters.

2. Use of cones.

3. Use of fluted cylinders.

4. Use of perforated cylinders.

Cylindrical Roller Pug-mills. — These machines, which are not very complicated, consist of two solid cast-iron supports fixed upon wooden joists or a block of masonry. Between

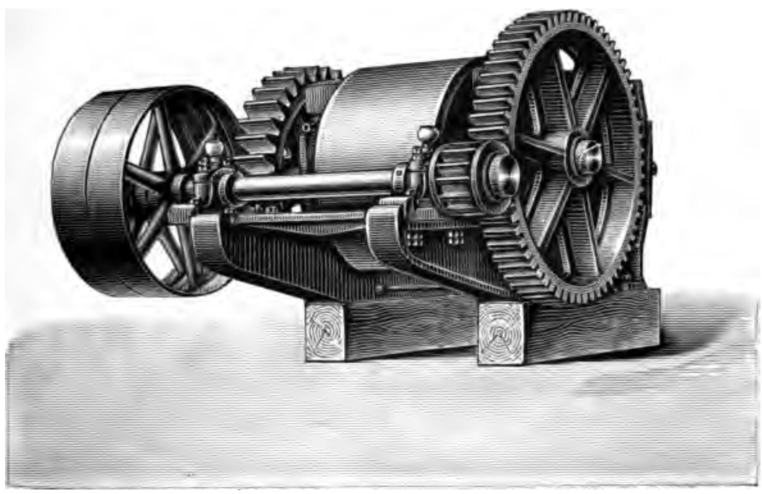


Fig. 69. – Pug-mill with Rolling Cylinders (Jacobi).

these supports are placed two cast-iron rollers, one of which receives the motion direct and transmits it to the second by means of a differential gearing (Fig. 69). Over the two rollers is placed a hopper into which the clay is put.

At a certain distance (which can be regulated at will) from each roller is a steel blade acting as a scraper. Above the rollers is the hopper, as can be seen in Fig. 70.

Cone-roller Pug-mills.—These differ from the foregoing only in the conical form of the crushers and their arrangement. The smaller diameter of the one being placed in front of the larger diameter of the other, an unequal speed at the circumferences

is caused for the same number of turns; hence blending occurs (Fig. 71).

The use of cones would be more advantageous, from the

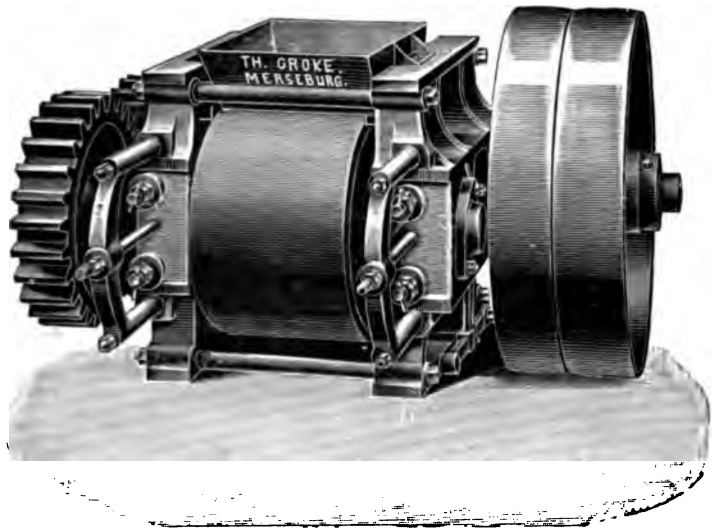


Fig. 70.—Pug-mill with Rolling-Cylinders (Groke).

point of view of output, than that of cylinders of the same diameter. To regulate the speed a flywheel is attached to the gear-shaft (Fig. 71).

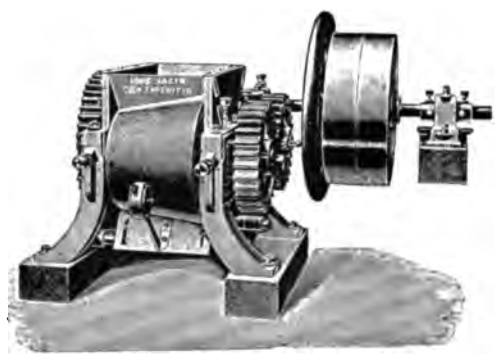


Fig. 71.—Pug-mill with Rolling Cones (Jäger).

Rolling Machines with Fluted Cylinders or Cones. — The blending of the clays is increased by the use of fluted rollers; the projections of one roller enter the depressions of the other. The shape of these flutings is, however, variable (see Figs. 72

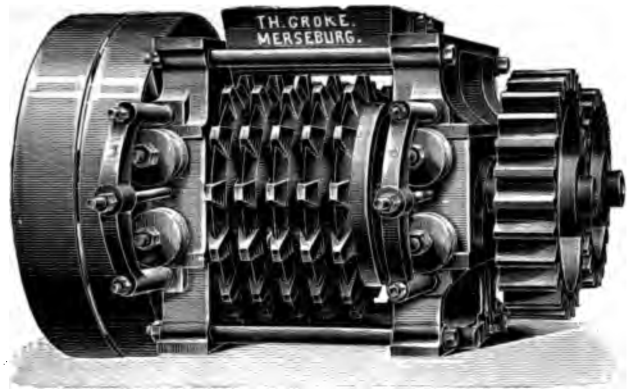


Fig. 72.—Rolling Machine with Fluted Cylinders (Groke).

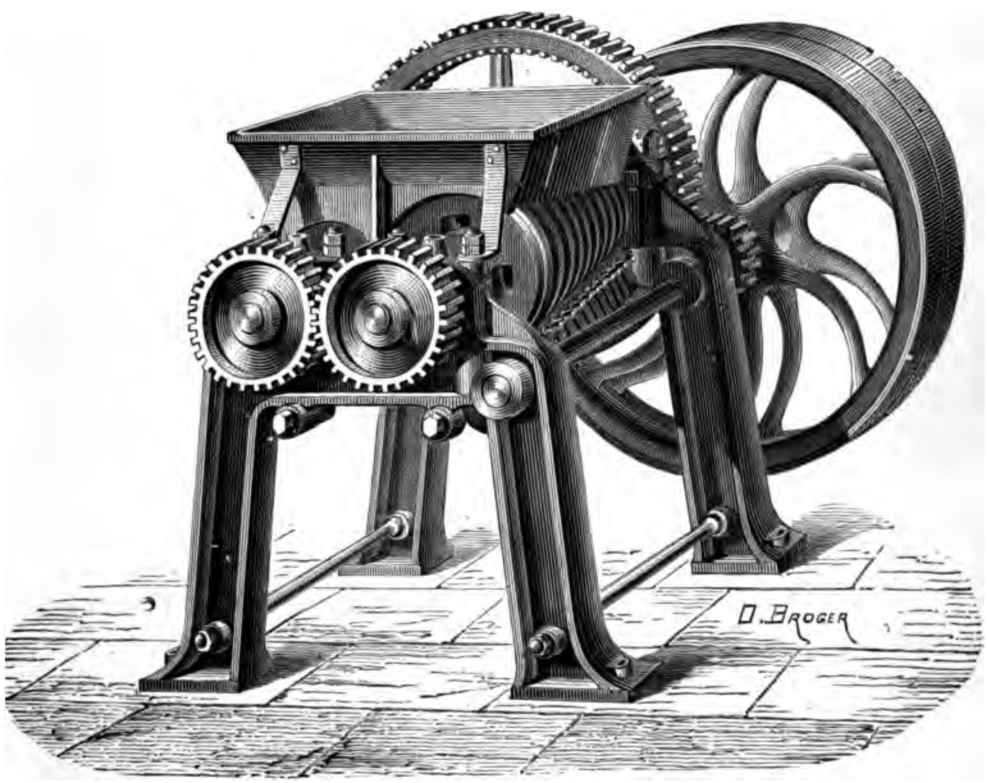


Fig. 73.—Rolling Machine with Fluted Cones (Boulet).

and 73). The speed of the rollers being the same, there is a difference of speed between the surface of a hollow and the surface of a projection which produces a tearing apart of the clay simultaneously with the flattening.

By using fluted cones this effect is increased. Thus it is that with the Boulet machines (Fig. 73) a single passage through it turns a mixture of differently coloured clays into a paste of uniform colour.

The flutings get filled with clay during the operation, but scraping combs, placed above, constantly clean them.

Rollers with Perforated Cylinders. — These machines are specially constructed for blending hard clays. They were invented by M. Dumont, and are now built by M. Lacroix. They consist of strong cylinders pierced with holes which are very close together and have a diameter of from 12 to 13

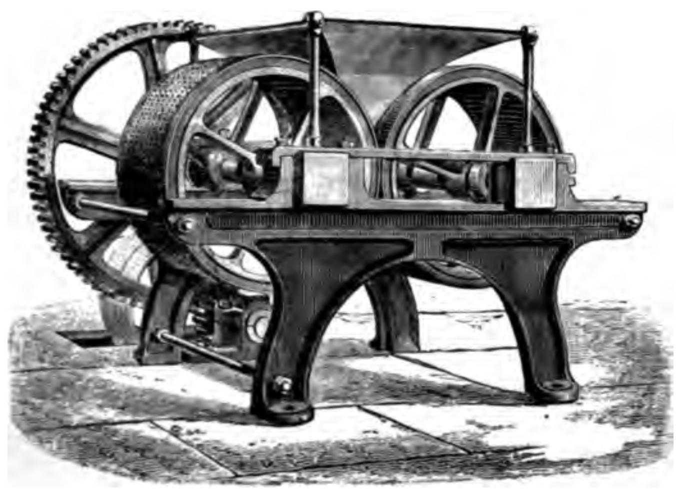


Fig. 74.—Dumont Perforated Cylinders (Lacroix).

millimetres (Fig. 74). The two cylinders touch one another, and the one receiving motion transmits it to the other by contact.

After the clay has been passed between ordinary cylinders, it is thrown by means of the hopper between the perforated cylinders, and as they press one against the other it is forced to pass through the holes when drawn down by the rotation.

Thus it penetrates into the interior of the cylinders in the form of endless curls, splitting up into small pieces which roll round one another before reaching the ground. This process develops the plastic qualities of the clay.

IV. *Pug-mills with Crushing Cylinders.*

A. VERTICAL PUG-MILLS.—When the clays contain small impurities such as limestone, lumps of hard clay, etc., it is important that they should be mixed to avoid accidents in

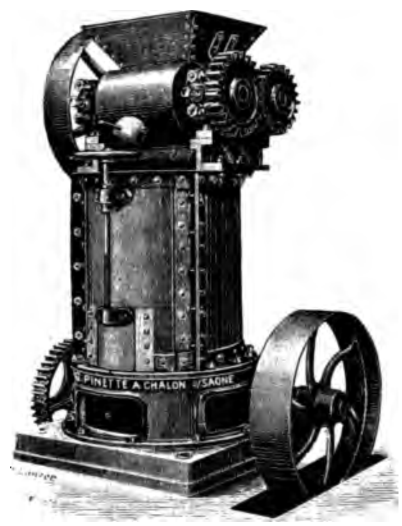


Fig. 75.—Vertical Pug-mill with Crushing Cylinders (Pinette).

baking. As pugging would be insufficient to remove them, the pug-mill is fitted with a pair of cylinders whose function is to crush these bodies. Fig. 75 shows a machine of this kind.

The cylinders and the pug-mill are worked separately; the latter is moved from below, and does not differ from an ordinary pug-mill. The clay having been introduced by the hopper above, is crushed by the cylinders and falls into the pug-mill, whence it issues by the lower door.

B. HORIZONTAL PUG-MILLS.—The two crushers are placed over the entrance to the pug-mill; they may be cylindrical

(Fig. 76) or conical (Fig. 77), and are driven from the belt-wheel of the pug-mill by means of intermediary cog-wheels, or are worked separately (Fig. 77).

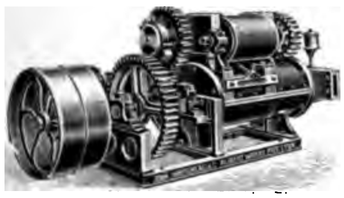


Fig. 76. Horizontal Pug-mill with Crushing Cylinders (Whitehead).

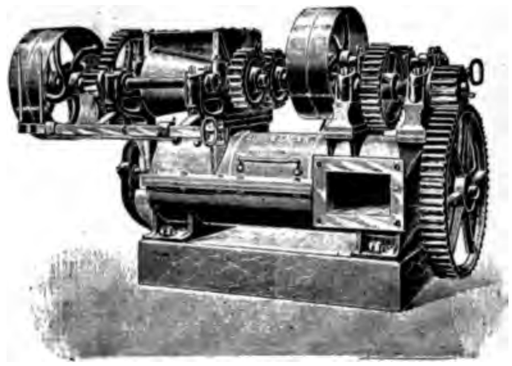


Fig. 77.—Horizontal Pug-mill with Crushing Cones (Jäger).

C. Double Cylinders.—These are placed one over the other, the use of the first pair being especially to crush and

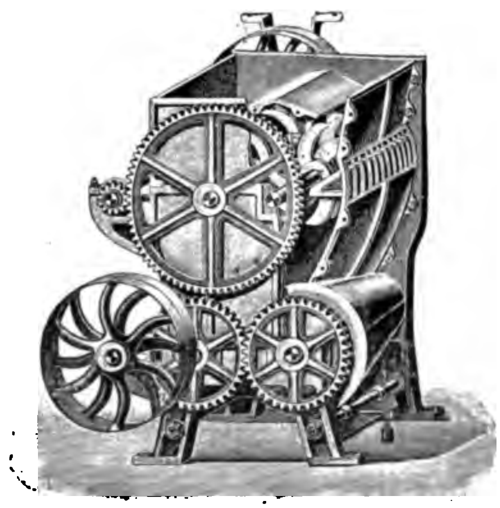


Fig. 78. Cone Rolling Machine with Dividing Apparatus above (Jäger).

divide the masses of clay, to break up the little hard bodies, and thus to facilitate rolling by the second pair of cylinders.

When it is required to split up the clay, the rolling machine

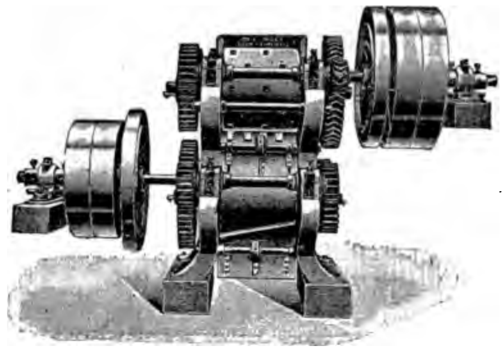


Fig. 79.—Rolling Machine with Crushing Cylinders above (Jäger).

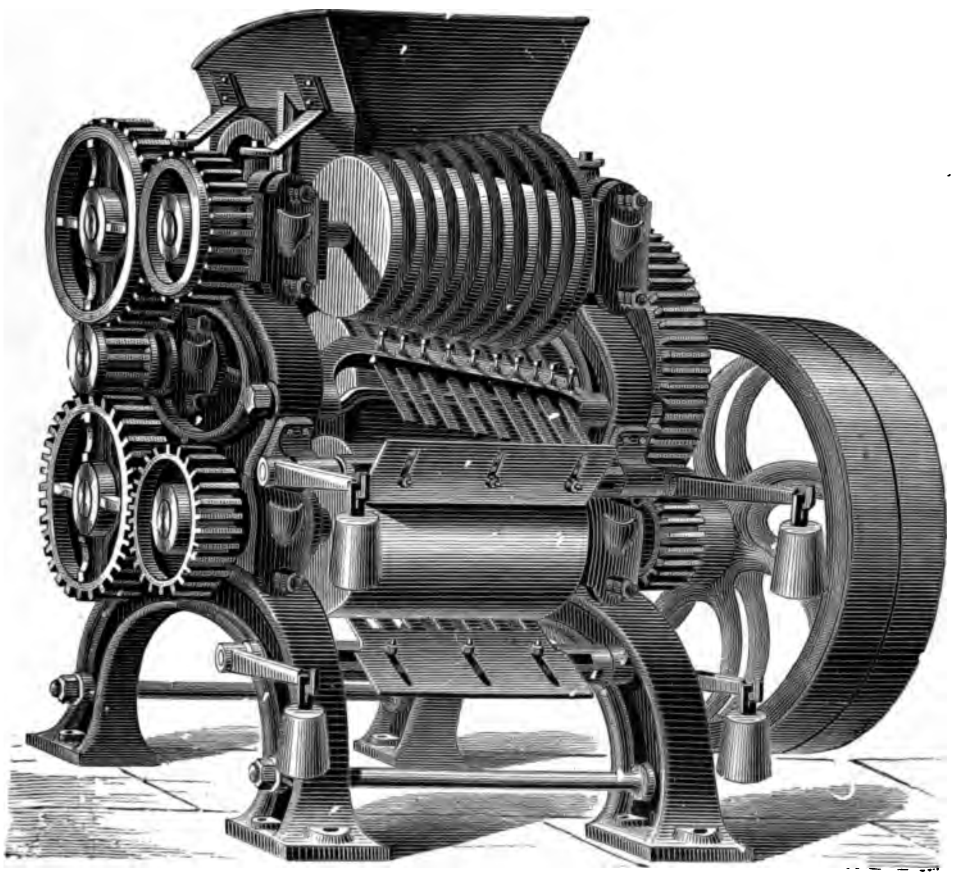


Fig. 80.—Rolling Machine with Fluted Cones above (Boulet).

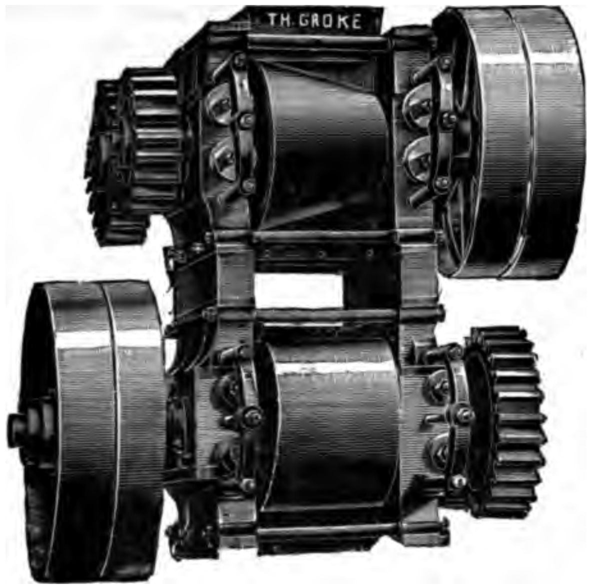


Fig. 81. Rolling Machine with Joined Cones above (Groke).

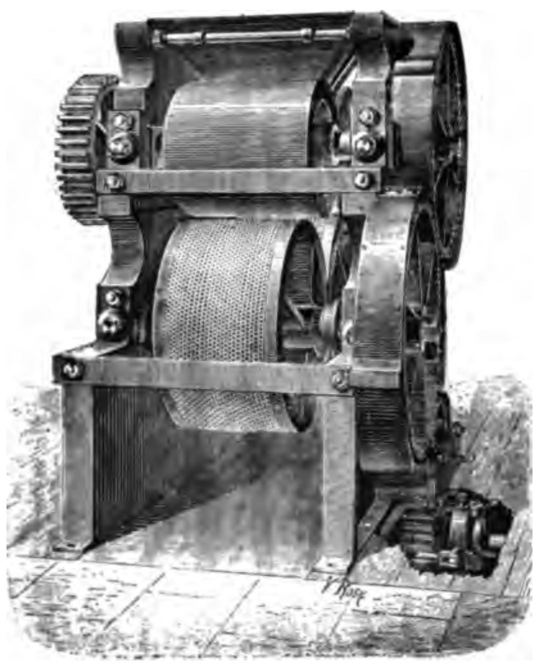


Fig. 82. -Perforated Cylinders with Crushing Cylinders above (Lacroix).

is surmounted by a special apparatus consisting of curved blades fixed to two shafts turned in opposite directions. These blades pass through the intervals of a kind of comb fixed to the sides of the machine. The clay, having been thrown from above on to a doubly inclined plate, spreads between the blade and the comb, and being drawn down by the rotation, is split up while passing through the hollows and falls between the cones of the roller (Fig. 78).

If the clays contain large lumps, crushing cylinders with points (Fig. 79) are used.

The double roller represented in Fig. 80 has a pair of fluted cones and a pair of cylinders.

The position of these may be inverted, as in the double roller of Fig. 81, which comprises a pair of cones and another pair of cylinders.

Finally, above the Dumont granulating cylinders are placed crushing cylinders to break up the hard lumps in the clay (Fig. 82).

INFORMATION AS TO THE DIFFERENT MACHINES USED IN THE PREPARATION OF CLAY.

ROLLING MACHINES.

Maker	No.	Rollers. Length.	Rollers. Diam.	Pulleys.	Turns.	Weight.	Horse-power.	Output. Bricks.	Price. Frs.	Remarks.
Jacobi (Fig. 69)	2	0.35	0.35	0.60–0.14	...	700	2	1800	625	
	4	0.35	0.50	0.60 0.14	...	1700	4	3000	1285	
	6	0.45	0.70	0.70 0.20	...	3300	6	5000	2025	
Jäger (Fig. 71)	1	0.40	0.50	0.75–0.15	130	1600	2–3	8000–1200	1250	The rollers are conical, and the diameter shown is that of the broader end.
	2	0.50	0.55	0.90–0.15	150	2300	4–5	1500–2400	1750	
	4	0.60	0.87	1.20–0.22	140	4700	6–8	3000–4500	3000	
Groke (Fig. 72)	10	0.47	...	0.65–0.13	150	1520	1–2	...	1500	Fluted rollers } A reduction of 25 per cent. is made on catalogue prices.
	11	0.47	...	0.70–0.13	150	1930	2–3	...	1920	,, ,,
	12	0.55	...	0.90–0.13	150	2600	3–4	...	2320	,, ,,
Boulet (Fig. 73)	...	...	...	1.00–0.11	180	1500	3	700 900	...	,, ,,
Lacroix (Fig. 74)	...	0.25	0.70	1.20 0.11	100	2000	5	1500–2000	2500	Perforated cylinders.
ROLLING MACHINE WITH VERTICAL PUG-MILL.										
Pinette (Fig. 75)	...	...	...	0.88–0.12	82	1500	2	...	1550	
ROLLING MACHINE WITH HORIZONTAL PUG-MILL.										Cone-pulleys. / Number of Turns.
Jager (Fig. 77)	1	...	...	0.64–0.12	120	2000	3 4	400–500	1900	0.64–0.12 / 130
	2	...	...	0.64–0.13	140	3300	6–8	800–1200	2750	0.64–0.13 / 140
	3	...	...	0.75–0.15	150	4500	9–12	1800–2500	4000	0.73–0.15 / 150
Whitehead (Fig. 76)	...	...	...	...	...	3200	8	1000–1200	2175	Cylindrical rollers.
DOUBLE ROLLERS.										
Boulet (Fig. 80)	...	...	...	1.00–0.11	150	3300	5	1500–1800	...	Upper rollers conical and fluted, lower rollers cylindrical.
Jäger (Fig. 79)	1	0.40	0.41	0.75–0.15	100 / 125	3200	4–5	800–1200	2500	Upper rollers cylindrical and with points, lower conical.
	2	0.50	0.55	0.90 0.15	100 / 150	5400	6–7	1500–2400	8750	
	3	0.60	0.55	0.90–0.18	115 / 150	7000	8–10	2000–3000	4750	
	4	0.60	0.72	1.00–0.20 / 1.20–0.22	110 / 140	9500	10–13	3000–4500	6100	
Lacroix (Fig. 82)	...	...	...	1.00–0.11	150	3300	5–6	1500–1800	3600	Upper rollers cylindrical, lower perforated.

		Grindstones. Diam.	Grindstones. Length.	Pulleys. Dimension.	Pulleys. Turns.			Output per hour.		
MIXING MILLS.										
Boulet et Cie (Fig. 21)	Ordinary		..	0.75–0.11	110–120	1000	1	3 cub. metres.	...	The output of mixing mills varies wit the moisture of the clay.
	Biconical		...	1.00–0.11	150	1100	2	5-6 c.m.	...	
Lacroix (Fig. 20)	...	...	..	1.00–0.11	150	1100	1	3 c.m.	**1000**	
Pinette (Fig. 19)	...	...	...	0.80–0.12	160	1000	2	2 c.m.	**1250**	
CRUSHING CYLINDERS.										
Boulet et Cie (Fig. 28)	...	...	0.70	1.20–0.15	90	3500	4–5	2 to 3 c.m.	..	The bricks are taken as having dimensions 0.22 × 0.11 × 0.06.
Joly (Fig. 29)	...	...	...	...	...	1400	...	...	**1500**	
Johnson (Fig. 30)	...	...	...	0.90–0.16	120	5000	6	2500 bricks.	**2500**	
Whitehead (Fig. 32)	1	0.50	0.50	...	...	2800	3	...	**1400**	
	2	0.60	0.60	...	...	4000	4	...	**1975**	
CRUSHING MILLS.										
Jannot (Fig. 33)	1	1.50	...	0.80–0.10	72	2,100	2–3	...	**1500**	These prices do not include packing, which varies from 30 to 50 francs.
	2	1.85	...	1.00–0.12	66	3,400	3-4	...	**2200**	
Luce (Fig. 34)	...	...	...	...	...	...	...	...	**1200 to 1900 frs.**	Are made with one or two grindstones.
Groke (Fig. 35)	12	1.00	0.25	0.75–0.15	100	5,800	4	400 kilos	**4,500**	Weight of one grindstone, 900 k. (Reduction of 25 on these prices.)
	13	1.20	0.30	1.20–0.16	80	10,300	6 8	600 ,,	**6,800**	,, ,, ,, 1950
	14	1.50	0.40	1.40–0.18	75	15,650	10–12	1500 ,,	**10,000**	,, ,, ,, 3000
	15	1.80	0.50	1.60–0.20	60	21,200	12–15	2200 ,,	**13,750**	,, ,, ,, 5000
Jäger (Fig. 39)	1	1.00	0.30	1.00–0.18	100	5,400	5	750 ,,	**3,625**	,, ,, ,, 1100
	2	1.20	0.35	1.20–0.20	100	7,800	9	1000 ,,	**4,875**	,, ,, ,, 2000
	3	1.50	0.43	1.20–0.22	100	15,000	12	1500 ,,	**7,500**	,, ,, ,, 3500
Johnson (Fig. 36)	...	...	...	1.20–0.16	136	17,200	10	2000 bricks.	**5,500**	
Whitehead (Fig. 37)	...	0.91	0.30	0.91–0.15	132	7,000	5	...	**2,500**	Packing extra, from 30 to 120 frs.
	...	1.27	0.30	1.06–0.15	120	10,600	6	...	**3,750**	
	...	1.62	0.38	1.22–0.15	108	12,200	8	...	**4,625**	
Whittaker (Fig. 38)	...	1.40	0.40	1.20–0.15	160	18,300	3	...	**5,350**	Weight of one grindstone, 2300 kil.

UNIVERSAL CRUSHERS.

Maker.	No.	Cages. Diam.	Cages. Length.	Dimensions of Pulleys.	No. of Turns.	Weight.	Horse-power.	Output.	Price.	Remarks.
Groke (Fig. 43)	1	0.60	...	0.30–0.15	950	900	6	600 kil.	1060	These machines are fitted with four cages.
	3	1.00	...	0.40–0.19	600	2450	15	3,500 ,,	2485	A reduction of 25 per cent. is made on these prices.
	5	1.20	...	0.50–0.22	500	3500	25	9,000 ,,	3175	The addition of two cages costs about 180 to 680 frs.
	6	1.50	...	0.60–0.25	400	5300	35	15,000 ,,	4325	
Jäger (Fig. 42)	1	0.60	...	0.22–0.12	900	1000	3	800 ,,	1185	
	3	1.00	...	0.25 0.20	850	2500	10	4,000 ,,	2810	
	4	1.25	...	0.30 0.20	650	4000	14	9,000 ,,	4250	
	5	1.50	...	0.50 0.26	450	5000	25	15,000 ,,	5250	

MOISTENING MACHINES.

1. *Simple.*

Maker.	No.	Cages. Diam.	Cages. Length.	Dimensions of Pulleys.	No. of Turns.	Weight.	Horse-power.	Output. Bricks.	Price.	Remarks.
Boulet (Fig. 48)	...	..	...	1.00–0.15	100	2500	3–4	...	...	
Jäger (Fig. 46)	0	...	...	0.64–0.11	100	750	3–4	800–1000	750	Reduction of 25 per cent. on these prices.
	1	...	...	0.64–0.12	100	1000	4–5	1000–1500	1900	
	2	...	...	0.75–0.15	100	1300	5–6	1800–2500	1200	
	3	...	...	0.90–0.15	100	1600	6 7	3000–4000	1450	
Johnson (Fig. 47)	...	...	...	0.76–0.16	120	1520	2	2000	775	
Groke (Fig. 45)	1	...	...	0.80–0.15	130	1600	3–4	1200–1500	1405	
	2	..	...	0.90 0.17	130	2100	4–6	1800 2500	1685	
	3	...	...	1.10–0.18	130	3100	6–8	3000 4000	2310	
Whittaker (Fig. 44)	..	...	...	0.60–0.10	...	...	2–3	...	835	

2. *With rollers.*

Maker.	No.	Cages. Diam.	Cages. Length.	Dimensions of Pulleys.	No. of Turns.	Weight.	Horse-power.	Output.	Price.	Remarks.	Turns.
Jäger (Fig. 50)	1	0.40	0.41	0.64–0.12	100	4,000	7–9	800–1200	3250	Pulleys of cylinders. I. 0.90 × 0.15.	130
	2	0.50	0.55	0.75–0.15	100	6,700	11–13	1800–2500	4950	II. 0.90 × 0.15.	100
	4	0.60	0.72	0.90–0.15	100	11,100	16–20	3000–4000	6200	IV. 1.00 × 0.20.	110
Lobin (Fig. 51)	...	0.60	0.55	0.80–0.15	110	1,200	10	30 to 40 c.m.	2750	Pulleys of cones. II. 0.90 × 0.15.	150
										IV. 1.20 × 0.22.	140

VERTICAL PUG-MILLS.

1. Worked by animal power.

		Cylindrical Pan. Height.	Diam.							
Boulet (Fig. 55)	...	...	...	...	...	...	...	...	...	
Joly (Fig. 57)	...	0.80	0.30	...	...	800	1	1 c.m.	**700**	Double-pan blender.
Whitehead (Fig. 56)	1	1.02	0.53	...	...	...	1	...	**356**	
	2	1.22	0.53	...	...	760	1	...	**400**	
	3	1.52	0.61	...	...	864	1	...	**450**	
2. Worked by steam power.										
(a) From above.								Bricks.		
Boulet (Fig. 61)	...	...	...	1.00-0.11	135	...	2-4	1500-2400	...	Sheet-iron pan.
Joly (Figs. 58 and 60)	1	1.10	0.60	0.95-0.15	55	1200	4	2 c.m.	**1200**	Sheet-iron pan.
	2	1.20	0.70	1.10-0.15	60	1300	4-5	2 c.m.500	**1260**	
	3	1.20	0.70	1.30-0.16	60	2200	4-5	1500-2000	**1760**	Cast-iron pan.
Sachsenberg (Fig. 62)	*a*	...	0.45	0.52-0.10	100	600	1-2	600-700	**780**	
	b	...	0.50	0.63-0.11	100	700	2-3	700-1200	**860**	
	c	...	0.63	0.76-0.12	100	1500	3-4	1200-2000	**1250**	
	d	...	0.75	1.00-0.16	110	2750	5-6	2500-3500	**2370**	
Whittaker	...	...	0.60	0.75-0.12	165	...	...	2000-3000	**1610**	F. o. b. Liverpool.
(b) From below.										
Boulet (Fig. 65)	...	...	...	1.00-0.11	120	2000	5	1500-2000	...	
Jäger (Fig. 63)	0	...	...	0.75-0.15	75	1000	2-4	500-800	**1125**	
	1	...	...	0.90-0.15	90	1550	4-5	1000-1400	**1375**	
	2	...	...	0.90-0.18	90	2100	6-7	1600-2000	**1700**	
Joly (Fig. 64)	...	1.20	0.70	1.30-0.16	60	2500	4-5	1500-2000	**2200**	
HORIZONTAL PUG-MILLS.										
Jäger (Fig. 66)	1	...	...	0.40-0.12	170	1300	2-3	300-500	**1200**	
	2	...	...	0.64-0.13	170	1800	4-6	800-1200	**1550**	
	3	...	...	0.75-0.15	170	2400	7-10	1800-2500	**1900**	
Sachsenberg (Fig. 68)	*a*	...	0.40	0.52-0.11	100	1100	2-3	300-500	**1170**	
	b	...	0.50	0.63-0.12	100	1600	3-4	500-1200	**1560**	
	c	...	0.63	0.76-0.13	120	2250	4-5	1500-2000	**1710**	
	d	...	0.80	0.78-0.16	130	4000	6-7	4000-5000	**2880**	

CHAPTER III.

BRICKS.

IN § 1 of this chapter we shall study the different phases of the manufacture of bricks: moulding, drying, and firing; § 2 will be reserved for the examination of the shapes, dimensions, and decoration of bricks; and in § 3 we shall point out their uses and their applications as well as their history.

§ 1. MANUFACTURE.

(1) **Moulding.** — From the most distant antiquity this moulding has been performed by hand by methods which probably differ very little from that which is called Flemish or Walloon. The simplicity of this process, the few tools required, its small cost, the absence of large expenses of installation, and the great output which it allows, were calculated to cause it to be considered as the only one possible. And in fact it is admirably suited for the manufacture of bricks which are intended for large buildings distant from centres of production but near beds of clay. The work is carried on on the spot. Small brickworks, and even large ones, have employed and still employ this process to a great extent, but it is no longer the only one. Nearly a hundred years have passed since those hand machines appeared which produced bricks by pressing the clay in moulds when it came from the pit. In this way the extraction of clay for weathering was avoided, and a considerable economy effected. No doubt the bricks so made are not as good as those made by hand, but for what are called native bricks the difference was not very noticeable.

Another valuable advantage was that the work and the presses were no longer so much subjected to the inclemencies of the summer. We know in fact that everything in the Walloon method is done in the open air, and thus a rainy summer causes frequent stoppage of work and consequent loss. We have no precise documents as to the invention of machines for making bricks by expression, and we do not know who recommended the use of die machines, but we may say that these discoveries date from the beginning of the century. For a long time the use of machines was very little extended; but the invention and the increasing use of hollow products and mechanical tiles, the manufacture of which requires machines, have considerably augmented the number of factories using machinery. This extension has been encouraged by the constantly increasing consumption of bricks, and the facility of transit which allows the distribution of the goods even outside the sphere of action of the factory.

Finally, the requirements of customers, who have gradually become used to fine machine-made productions and will have no others, have something to do with the fact that in large towns and in factory buildings hand-made bricks are no longer to be seen.

But in a great number of local works the primitive method, especially for the so-called native bricks, is the only one employed on account of its simplicity.

There are then two quite distinct processes of brick manufacture—

1. The process by hand carried out in the open air; 2. the process by machinery carried out in the open air or in factories.

The latter, as we shall see later on, is subdivided under several headings according to the way in which the machines work, and according as they are driven by hand, by animal power, or by steam.

Hand-moulding.—The installation of a manufacture of this kind requires plenty of room, for the bricks, which are laid singly on the ground, must have the time to harden before being put

into *hacks*. The first thing to be done is to choose a situation. A piece of ground is chosen, near the heap of clay which has already been weathered, and on a slope, in order that the rain-water may run off easily. This water, collected in a pool, may be used to moisten the clay. The ground is afterwards scraped with a shovel to remove inequalities, and is then smoothed by means of a *scraper* (Fig. 84*b*), a tool composed of a board of about 0.50 metres long, and 0.10 to 0.15 metres broad, furnished with a handle placed at right angles to the board.

Tools. We have mentioned those used in preparing the clay: for moulding there are required: a special square table, a sand-box, also called a "minette," two double moulds, a "plane" or *strike*, a bucket or tub, and finally some wheelbarrows for transporting the clay from the heap to the moulding-table, and the bricks from the ground to the hack.

Fig. 83.

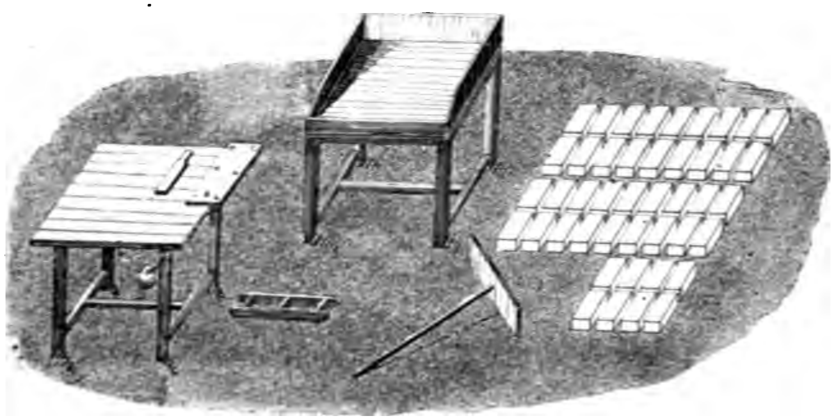


Fig. 84. Fig. 84*a*. Fig. 84*b*. Fig. 85.

Fig. 83. Sand-box. Fig. 84. —Moulding-table. Fig. 84*a*. Double Mould. Fig. 84*b*. Scraper. Fig. 85.—Bricks laid on the Ground.

The moulding-table (Fig. 84) has four legs and is about 0.80 metres high, and has about one square metre of surface. At one corner a part of the board has been cut off, of slightly larger dimensions than the mould laid flat. This portion is covered with a plate of thin iron to prevent wearing away, for it is here that the moulding is done.

This protected piece of wood is fixed to the upright of the table by means of two hinges on which it turns; and in order that it may lie flat in its normal position, a chain is fixed to it, with a mass as counterpoise—generally a stone.

The sand-box or "minette" (Fig. 83) is a square wooden tray placed at the same height as the table, and about 0.20 metres deep. It is filled with fine and very dry sand, or, more economically still, with crushed and sifted terra-cotta.

The mould (Fig. 84*a*) is double and made of beech-wood of the best quality of about 1 centimetre thick; it is covered at the edges with plates of sheet-iron to prevent wear. Sometimes it is furnished with a bottom, to make one of the faces of the brick smoother.

The use of the single mould is a waste of time, as the moulder can easily take at one time the quantity of clay required for two bricks. The dimensions of the moulds must be calculated according to the amount of contraction which the clay will undergo in drying and firing.

If the brick is to be stamped, the mould must be higher than for an ordinary brick. Contraction is generally estimated at from 5 to 10 per cent.—that is to say, in order to have a brick $0.22 \times 0.105 \times 0.05$ after firing, a mould of about $0.23 \times 0.115 \times 0.052$ must be used, contraction acting principally on the breadth of the brick on account of its position in firing. But the contraction of clays is very variable, and experience alone can guide us.

The "plane" or strike (Fig. 84) is a plain oak board, well finished, and having one end shaped as a handle. Sometimes a steel blade is used.

Moulding.—This kind of work is mainly done by people of Picardy and Flanders. They go in gangs during the summer to the place of manufacture, and return home in the autumn. There are also some moulders of settled habitation. The number of workmen forming a "brick-table" is variable. For regular and constant work four are required: a moulder, a separator, a barrow-man, and a mould-carrier. But it happens sometimes, if the moulder is an active worker, that the barrow-man cannot keep

up the supply of clay and at the same time stack the bricks. In this case a fifth man is required; as his work, however, is irregular, many gangs prefer to manage with four, and when the stacking of the bricks is in arrears, the moulding is stopped, and all assist in carrying the bricks to the stack.

The moulding is done in this way: the moulder takes with both hands a sufficient quantity from the heap of clay which the barrow-man has placed at his feet, rolls it into a ball, and raising it over his head throws it with force into the mould; he then completes the forming of the mass by a vigorous kneading, which he begins at the side farthest from him. Afterwards he takes his strike, which is lying in a bucket of water on the table, and holding it in both hands passes one of its angles along the edges of the mould, afterwards taking off the excess of clay, which he throws with one hand back on to the heap while with the other he replaces the strike in the bucket.

The mould-carrier then seizes the mould by its two ends, and, resting lightly upon it, he swings over the movable board so as to turn the bricks up on edge, and carries them away, resting them slightly against his body. When he arrives at the ground where they are to be laid, he proceeds to demould them by placing the mould on the ground, still up on edge, quickly inclining it, and then laying it flat; then, by a slight jerk, he removes the mould cleanly.

In this way the brick is laid on the ground without loss of shape; some practice is required for doing this well, but the boys soon learn the knack. The workman then goes to the sand-box which stands near the table, plunges the mould into the sand, and returns for another, which the moulder has filled during his absence. When the mould is taken from the table, the moulder throws a little sand on the iron plate, takes the mould from the sand-box, and places it upon the plate (a stop prevents it from going too far), and proceeds as before. From time to time the moulds are cleaned with a wooden knife and washed; the whole installation is moved if the rows of bricks come too near the table.

The moulder need not move during his work; everything is

within reach of his hand. A good mould-carrier can nearly always keep up with the moulder, but he must be active and perform all his work promptly.

The bricks are left lying until they have become sufficiently firm to be handled without loss of shape; this is tested by pressing upon them with the finger, which should leave no mark. Naturally this period is variable according to the weather, and may be from twelve to forty-eight hours. When once the proper firmness is acquired, the bricks are edged off by removing the seams with a wooden knife, and they are placed on edge without being moved from the ground by turning them on one corner. They are then put on barrows and wheeled to the place where they are to be stacked.

If rain threatens, care must be taken not to leave the bricks up on edge, for in that position rain deforms them more easily than when they are laid flat.

Production and Net Cost.—The production depends upon the skill and strength of the moulder. When he can make 500 to 600 bricks per hour without trouble he may be considered to be a good workman.

Hand moulding is paid by the piece, and the price varies with the country. In the North of France and in Belgium the pay is from 2 fr. to 2 fr. 50; in the neighbourhood of Rouen and Paris, it averages 4 to 5 fr. per 1000. It rose to 6 fr. during the great boom which preceded the crisis in the building trade in 1882.

This pay includes the preparation of the clay (but not its extraction), the moulding of the bricks, the shaving of the seams, and stacking, and also superintendence up to the time when the bricks are taken away for firing.

The sand is prepared by the gang but provided by the manufacturer.

Space Necessary.—The space necessary for a "brick-table" is rather large. There must be an area of at least 600 square metres for laying down the bricks; besides this there must be room for the clay-heap, stacks for drying, kilns, paths, and the place where the clay is extracted during the winter.

A factory for making bricks by hand must then consist of two distinct portions: the space where the moulding, drying, and firing are carried on, and the place of extraction. The arrangement of these spaces depends upon locality and facilities of communication, but the kiln should be placed as near as possible to the exit.

For the life of the pit, it is calculated that 1.250 cubic metres of virgin soil, which give 1.500 to 1.750 cubic metres of excavated clay, furnish about 1000 bricks (0.22 × 0.105 × 0.06). According to the thickness of the bed of clay, it will be easy to calculate the surface necessary for the annual output.

It sometimes happens that, in the same works, the upper stratum of the clay, called *weak clay*, is made into bricks by hand-presses, while the lower stratum, called *strong clay*, which cannot be treated in the press, is hand-moulded. In this case the hand-moulders begin work when the upper stratum has been taken away.

Hand-moulding after Mechanical Preparation of the Paste. —There are some brickworks whose annual production is as much as ten millions, and which are worked by hand. This large quantity of bricks requires a daily consumption of vast quantities of material.

It is advisable, in order to reduce as far as possible the cost, to prepare the paste mechanically, and to transport it cheaply to the place of manufacture. The plan and section in Fig. 86 show an installation of this type, furnished with two pug-mills similar to those represented in Fig. 63.

The clay when extracted from the pit is loaded on little waggons and taken to the pug-mills by an inclined plane *ff*. This inclined plane is easily removed and, with a sufficiently long cable, covers a large radius. It may be replaced by an endless belt sloping downwards, on which the clay brought by the waggons is thrown. In front of, and at the same height as, the issuing orifice of the pug-mills are flat cars which run on rails from the mills to the place of moulding. Each car carries enough to make from 100 to 150 bricks; they follow one another

without interruption, and are so arranged that the moulding is carried out on the platform of the car itself.

The pug-mills are worked by a stationary engine, and produce per hour a sufficient quantity of paste to make 2000 to 2500 bricks. The net cost, extraction not included, which is the same in both cases, is estimated as follows; it may be remarked,

BRICK-MAKING INSTALLATION FOR A DAILY PRODUCTION OF FROM 40,000 TO 50,000 HAND-MADE BRICKS.

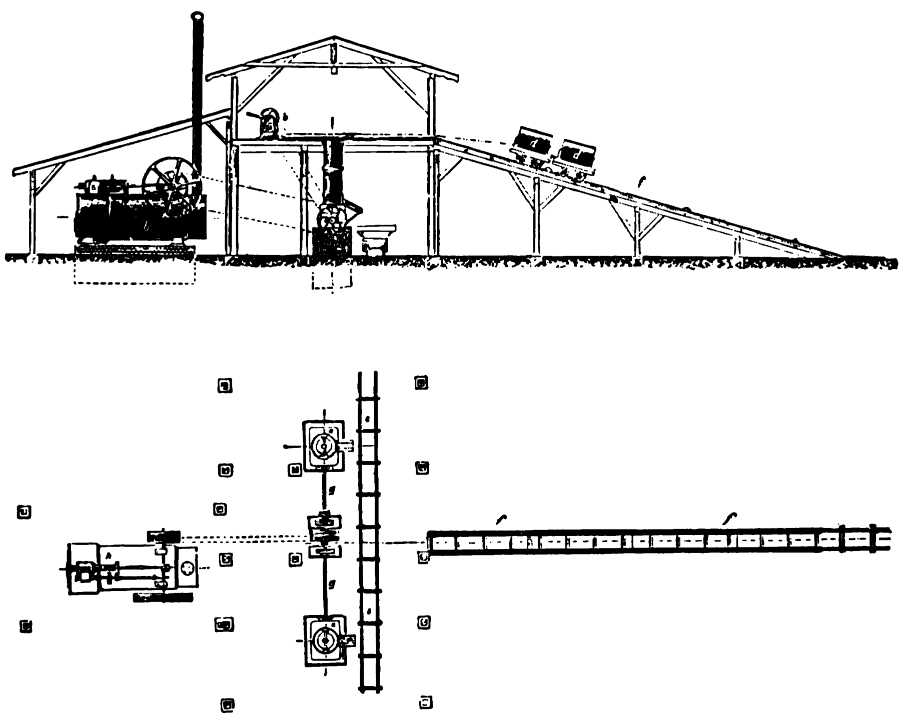


Fig. 86.—Section and Plan.

however, that the cost of labour, which is put down as 30 to 50 centimes an hour, is capable of reduction.

The economy which may be realised amounts to the difference between 4 or 5 francs, price for piece-work, and the sum mentioned below, that is to say, 1 or 2 francs per 1000, and from 10,000 to 20,000 francs for the 10,000 manufactured annually.

	Francs.	Francs.
Material.—A 20 horse-power engine	11,000	
2 pug-mills, at 2500 fr.	5,000	
1 windlass and cable	300	
8 waggons for transport, at 100 fr.	800	
30 waggons with platforms, at 60 fr	1,800	
Transmission of power and belting	300	
500 metres of rail, .50 m. gauge, at 3 fr. 20	1,600	
2 sets of points	180	
12 turn-tables, at 40 fr.	480	
Structure and inclined plane	2,500	
Moulds and tools, barrows	840	
Sundries	200	
	25,000	

	Francs.
Interest at 4 per cent.	1000
Sinking-fund at 10 per cent.	2500
	3500

		Francs.
Per thousand : $\frac{3,500}{10,000}$ = 0 fr.35		0.35
Labour, etc.—9 moulders, at 5 fr.	45 fr.	
9 boy mould-carriers, at 3 fr.	27	
4 boys to push waggons, at 3 fr.	12	
4 men to stack the bricks, at 4 fr.	16	
4 boys to edge off the bricks, at 3 fr.	12	
1 engine-driver	5	
Coal, 400 kil. at 25 fr. per 1000.	10	
Oil, repairs, etc.	5.50	
	132.50	
That is to say per thousand : $\frac{132 \text{ fr.} 50}{50}$ = 2 fr. 65		2.65
The cost of manufacture, with interest and depreciation, comes then to		3.00

Machine-moulding of Bricks.—The increasing demands of trade have caused, in brick-making as in so many other manufactures, the substitution of machine for hand work.

The invention of the Hoffmann continuous kilns, by perfecting to such a degree the firing processes, has also been one of the causes of the development of machinery in brickworks. Economy cannot be a factor favourable to the development of machinery, for if, in works having a large output, the cost of mechanical manufacture is no larger than that by hand, in works of moderate size, where there is a long cessation of work in the winter, interest and sinking-fund are factors to be taken into consideration. But what has gained the day for machines is

that they allow of the manufacture of articles impossible to make by hand.

Thus in the great centres of consumption, England, Germany, America, where millions of bricks are used annually, they are nearly all made by machinery. In France also numbers of brick and tile works produce by machinery.

The machines that have been invented for the mechanical manufacture of bricks, are as numerous as they are varied; but if we consider how a parallelopiped, regular like a brick, can be made out of clay, we must come to the conclusion that two processes only can be utilised: the first consists of compressing a certain quantity of clay by some means or other in moulds of the required shape; this is the principle of machines working by compression. The other process consists of forming out of clay suitably prepared a long prism having two of the dimensions of the brick, and of cutting it afterwards at regular intervals to get the third dimension. It is in this way that machines working by expression act.

In practice these principles may be applied in many different ways, hence we have a variety of machines possessing one common principle.

In classifying machines we must note the manner in which they carry out one of these principles, and also the degree of dampness of the paste used; it is evident that machines intended for treating firm or semi-firm clays are not suited for treating hard clays, and *vice versâ*.

This being so we have the following classification:—

- I. Machines working by compression
  - 1. On soft clay.
  - 2. On semi-firm or firm clay
    - By gradual pressure.
    - By shock.
  - 3. On dry clay.
- II. Machines working by expression
  - With semi-firm or firm clay
    - By propelling cylinders.
    - By pug-mill with expelling screws
      - Vertical.
      - Horizontal.
  - With hard clay.
    - By piston.

DESCRIPTION OF MACHINES FOR MAKING BRICKS.

I. **Machines Working by Compression.** — 1. ON SOFT CLAY.—These machines, which imitate hand work, operate upon soft clay previously prepared by a vertical or horizontal pug-mill attached to them. The wooden mould, which has six or seven compartments, is placed under the press, and when it is full is automatically expelled; a workman smooths the surface of the bricks with a scraper and passes the mould to the demoulder;

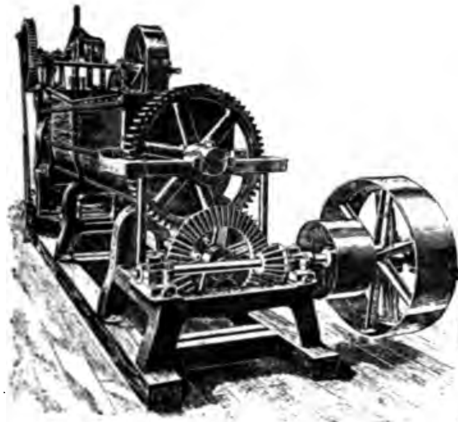


Fig. 87.—Horizontal Machine for Soft Paste worked by Steam.

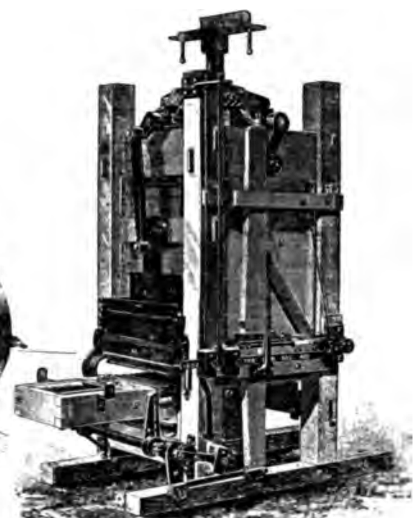


Fig. 88.—Vertical Machine for Soft Paste worked by Horse-gear.

the latter places the bricks on a board, which is carried to a drying ground or room. The empty mould is dipped in water and put under the press again. These machines, largely used in America, are suitable for thin clays which draw badly.

With a horse the machine in Fig. 88 (2800 fr.) produces 600 to 900 bricks per hour; with two horses (2500 fr.) from 1200 to 1800 bricks. The machine (Fig. 87) which is worked by steam power (6300 fr.) produces from 3000 to 5000 bricks.

2. ON SEMI-FIRM OR FIRM CLAY.—*Lever Gradual Pressure Machines.*—The oldest of these, and the one always used in a

large number of works which make bricks of vegetable mould (lehm or tableland ooze), is composed (Fig. 89) of a low and very thick wooden table, pierced with a square hole at one end. Into this hole a copper double mould (Fig. 90) is introduced and fastened to the table by bolts which pass through the thickness of the table. The bottom of each mould is closed with a T-shaped piece of wood (Fig. 91) called *chandelle*, the top of which is covered with a copper plate. The two pieces are moved up and down smoothly in the mould by rack-work connected with two pinions worked by a winch. This motion is guided by an iron rod, passing through each of the two T-pieces and resting on a strong cross-bar which joins the two uprights of the machine.

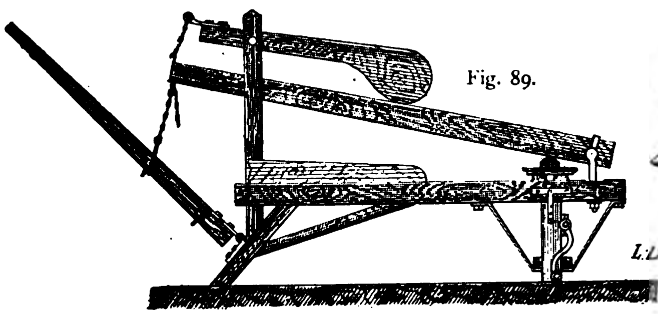


Fig. 89.

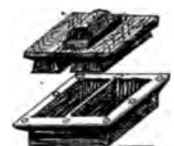


Fig. 90.

Fig. 91.

Fig. 89.—Lever Press for moulding Vegetable Moulds.
Fig. 90.—Cap and Double Mould. Fig. 91.—"Chandelle."

A first lever, movable round an axis, is connected by a chain to another lever, which is attached at one end to one foot of the table. This chain holds the lever by a collar which slides on an iron guide fixed to the lever. A wooden counterpoise called a *mouton*, which is pivoted on an axis, rests on the horizontal lever and keeps them both raised.

The working of this machine is simple and requires two men, at the most three. The clay is prepared as we have said. The workman who manages the lever takes a shovelful of this clay and throws it into the two moulds; the latter must not only be full but must overflow. He puts aside his shovel quickly, and, with the aid of his comrade, compresses the clay by striking it with his fists; then with a quick motion he takes the excess off

the moulds, one corner of which he discloses in order that the man who takes the cap (Fig. 90) may be able to see the place where he is to put it. Meanwhile the other man has placed himself at the end of the lever and leans upon it. The pressure is transmitted to the clay by the lever called *brebis*. After having given two or three pulls, the moulder quits the lever, which is drawn back by the counterpoise called *mouton*. The demoulder takes off the cap and turns the winch; the bricks come out of the mould, and the demoulder takes away the one on his side and puts it on a barrow with a platform which contains about fifty of them. His comrade puts his on the *brebis*, whence the other takes it to place it on the barrow. Meanwhile the moulder has taken a handful of powder from the table and has sprinkled the moulds,—the winch, left to itself, having been returned to its first position by the weight of the movable pieces forming the bottom of the moulds,—then he throws another shovelful of clay into these latter, and the process continues as before.

When a barrow is full the moulder pushes it forward a few metres and substitutes an empty one. The other workman has meanwhile been bringing as near as possible to the machine the clay which has been drawn in advance to replace that used. When the second barrow is full, the two moulders expose their productions in drying-places, generally open-air ones. Sometimes this part of the work is done by a third man who, in the intervals, prepares and draws the clay. These three men are able to make from 300 to 400 bricks an hour.

The length of the chain is so adjusted that the end of the lever touches the ground when the strongest pressure is used. This method of manufacture, simple as it is, requires a certain skill to be quickly carried out. Especially is this the case in putting on the cap, for it must at first trial be placed just over the moulds, and this is difficult owing to the excess of clay on the table. If it is put on badly one corner of the plates will strike against the mould, and compression cannot take place; it will have to be readjusted, and time will be lost. The moulder, too, must have the knack of putting the same quantity of clay in each

shovelful, in order that the bricks may have a uniform thickness. The fulling of the clay should be uniformly done, otherwise the bricks will be thicker at one end than the other. Bricks made in this way require to be fired thoroughly to acquire cohesion, and never, even when restamped, have the tenacity or the quality of blended bricks.

The machine above described has been modified in different ways. The framework is made of cast-iron (Fig. 92), the cap

Fig. 92.—Lever Press with Cast-iron Frame (Boulet).

Fig. 93.—Lever Press with Cast-iron Frame (Dupuy).

is hinged and held by a stirrup; the pressure instead of acting from above acts from below. The adjustment of the cap is thus simplified, and can be done by a young man.

In the Dupuy machine also (Fig. 93) the cap is movable about a hinge. The lever by its special position makes the operation more rapid, for the workman, instead of having to go from the moulds to the end of the lever, has only to turn round, and thus output is increased.

Another improvement is in the demoulding. In ordinary

machines, in order to keep the bottom of the moulds at the level of the platform, the workman is obliged to hold with his knee the winch which controls the pinions.

In the Dupuy machine the demoulding is done by the lever which, in the figure, the workman is holding in his hand. The bottom of the moulds is held by a special catch, and when the bricks are taken out the assistant, by means of the little lever at his side, releases the catch and the bottom falls into its place again. The moulds are of bronze, as also are the plates of the cap and bottom. As these latter wear out rather quickly in consequence of the friction, a hollow is formed between them and the sides of the mould, through which a little clay is forced under compression, and this makes seams in the bricks. It would be troublesome to be always renewing the plates. Therefore they are made of malleable bronze, and every two or three weeks they are beaten on an anvil to lengthen and broaden them, then they are fixed to the mould by screws or bolts.

The moulds also get worn ; the only inconvenience of this is the progressive increase in the dimensions of the brick ; when it becomes too large, the moulds are renewed.

Price and Output.—The wooden machine in Fig. 89 costs from 350 to 400 francs ; the Dupuy machine costs 600 francs and weighs 400 kilos—that is to say, nearly the same as the other. The output, as we have said, is from 300 to 400 bricks per hour ; labour is always paid by piece-work, at an average of 4 to 5 francs per thousand.

This kind of machine is extensively used in the neighbourhood of Paris, Rouen, Amiens, Saint-Quentin, etc., as well as abroad. *But it must not be forgotten that all kinds of clay cannot be used with them.* Weak vegetable moulds only can be treated, as the strong clays and potter's clays stick to the moulds and cannot be demoulded.

Machines Working by Shock.—To a certain extent the stamping presses, which we shall describe in connection with high-class bricks (Figs. 158–160), may be used for moulding certain raw clays coming from the pit. The clay is prepared as in the case of the preceding machines. It should be as fine as possible,

without lumps, and neither too damp nor too dry. The press-mould is movable. By means of a handle it is brought forward in front of the table, there it is filled, then returned to its former position, and with a rapid, violent blow the lever is depressed; the cap falls sharply and compresses the clay. The latter flies back and brings the lever forward again. The workman takes hold of it and replaces it in its former position. During this movement the movable bottom of the mould is taken away and the brick comes out. The output hardly reaches 200 to 250 bricks per hour.

Fig. 94.—Hand Press for moulding Coarse Clay (Chambrette Bellon).

This inconvenience does not exist in the perfected press shown in Fig. 94. The moulds, three in number, are fixed on a plate which revolves round one of the uprights of the machine. Compression is no longer exerted by the action of the cap only, but the lever acts simultaneously on the movable bottom and the cap, and so the two faces of the brick are equally pressed. The motion of the lever produces at the same time an automatic demoulding by means of a cam and jointed lever. The plate is kept by gear in its position of compression.

The working of the machine is simple. While a boy takes

away the brick which has just come from the mould, another fills the empty mould, and a third workman turns the plate and works the lever.

The remarks we have made on these lever presses apply to the preceding machines, the use of which can only be interesting in certain special cases.

For complete description of these machines see paragraph on *Stamping of Bricks* (p. 161).

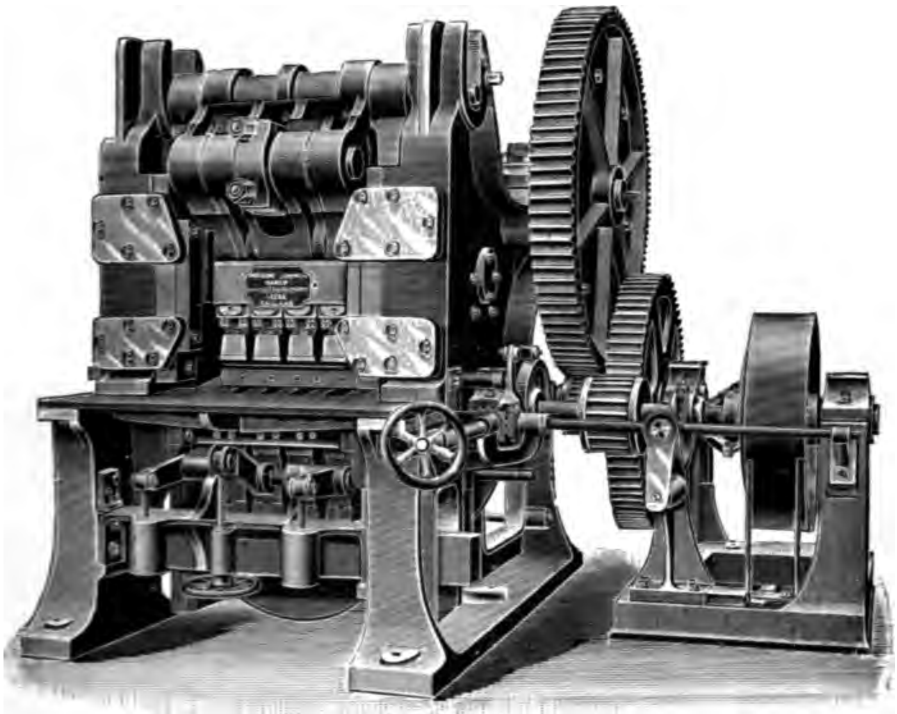


Fig. 95.—Press for making Bricks from Dry Clay (Johnson).

3. MOULDING POWDERED CLAY.—The machines used in this kind of moulding are of American or English construction; they act by strong compression in moulds on dried, pulverised, and moistened clay.

The pressure on each brick exercised by the pistons is as much as 125 tons! Therefore these powerful machines, a model of which is represented in Fig. 95, are constructed in a very solid manner. They absorb much power, and for a production of

2500 to 3000 bricks an hour a 25 horse-power steam-engine is required.

The number of moulds varies from 2 to 6, and the bricks go from the machine straight to the kiln.

In the Whittaker machine (Fig. 96) the pressure is also exerted by a piston, but each brick receives two compressions successively.

Fig. 97 represents a section of the machine. The powder

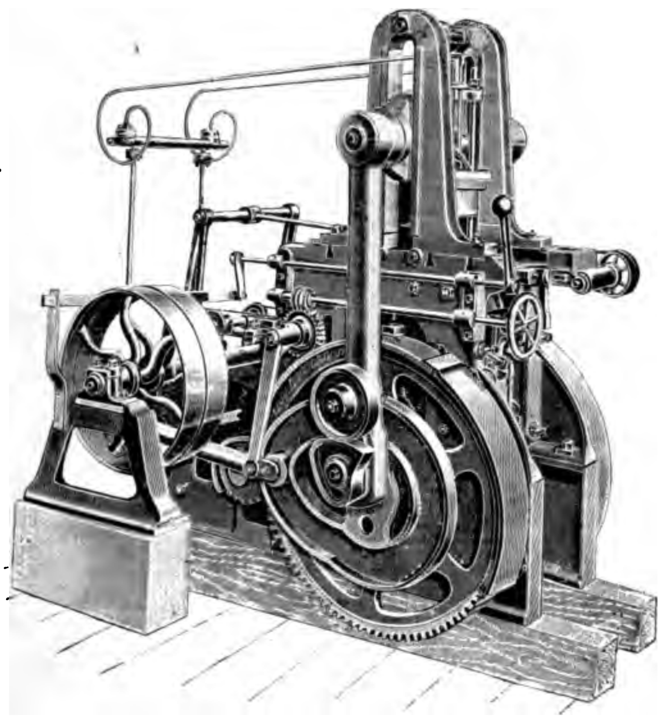


Fig. 96.—Press for making Bricks from Dry Clay (Whittaker).

arrives from the upper storey by a conduit furnished at its lower end with a hose which takes the clay into a mould. The mould when full is pushed under a piston, which makes a first compression; then the brick is pushed under the second piston while the first mould is filled with clay. The second compression completes the brick, which, when demoulded, is placed on an endless band by the same motion which brings the clay to be pressed under the first piston.

The bricks thus formed by great pressure require no drying; they are taken direct to the kiln.

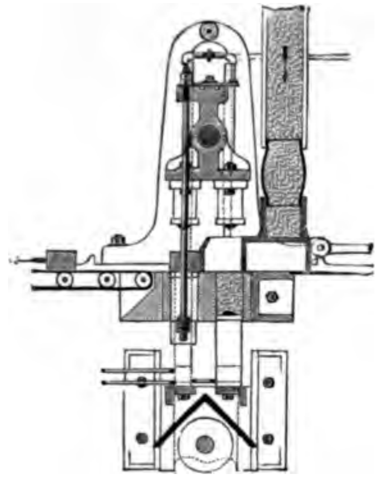


Fig. 97.—Section of the Parts of the Whittaker Press.

The mechanism moving the different parts of the machine is easily understood by the annexed figures.

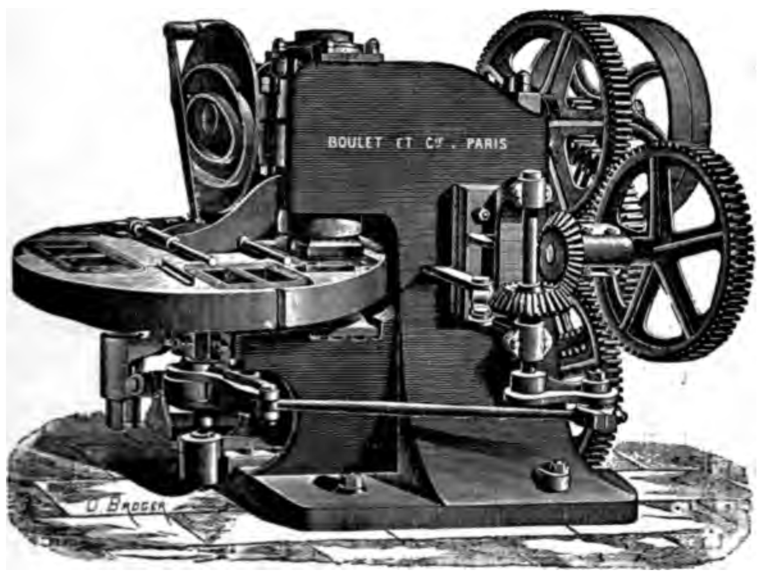


Fig. 98.—Press for making Bricks from Dry Clay, with Revolving Plate (Boulet).

The Boulet machine (Fig. 98) differs from the foregoing in the arrangement of the moulds which are placed in pairs on a

movable table. They are filled by hand; during the compression the table is motionless, then it turns automatically, and the pressed bricks are at the same time removed from the moulds.

Another machine with a turning table is represented by Fig. 99. A special arrangement in this machine permits of bricks with hollows perpendicular to the surface being made by it.

II. **Machines Working by Expression or Wire-drawing.**—The principle of these machines consists in the compression of

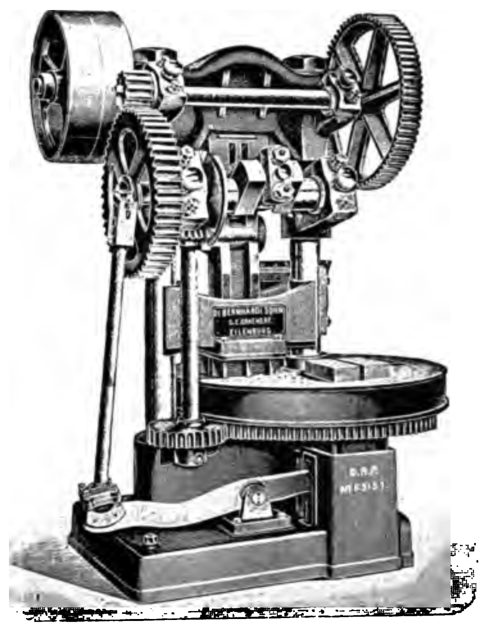


Fig. 99.—Press with Revolving Table (Bernhardi Sohn).

the clay, which has been suitably prepared and made into a more or less firm paste, into a space one end of which is formed of a special piece pierced with a hole and called a die. Through this opening, which has various shapes and sizes, the clay issues in the form of a continuous smooth-faced prism, and is received on to a special waggon, where it is cut into the required lengths.

There are three essential parts in these machines: 1. The machine proper, simple or with attached apparatus for the previous preparation or crushing of the clay.

2. The die, a very important instrument, which gives the shape to the bricks.

3. The cutter, which divides the prism of clay into bricks when it comes from the die.

Each of these parts requires a special description, for the parts and their arrangement, although the same result is aimed at, are different with different makers.

I. *Description of the Machines.*

Expression Machine with propelling Cylinders.—*General Remarks.*—It is difficult to say under what circumstances machines of this kind are preferable to screw machines; but we can state in what cases they can not be used. If it is true that clay can be used for these machines just as it comes from the pit, after having undergone a suitable moistening, the work will nevertheless be facilitated and the production increased by a previous pugging. This pugging is even indispensable for rich clays which have to be thinned; the mixture of the rich and the shortening matter is thus rendered a close one.

It is equally evident that if the clays contain stones or foreign matter they must undergo crushing before the pugging.

Personal experience has shown us that vegetable moulds (lehm or loess), which are always thin, cannot be worked alone by the powerful screw machines, as a too strong pugging makes the products brittle and unfit to be cut, while the same clay treated with a cylinder machine, even without previous pugging, gives fairly good results.

We may say then that, in questions like this, experience alone can guide us, according to the nature of the clays, and we must not hesitate, when circumstances require it, to abandon the screw machines, and replace them by cylinder machines with pug-mills attached. The Vaugirard brickworks in Paris, which use plastic clays, employ cylinder machines.

The principal parts of a machine with propelling cylinders (Figs. 100 and 101) are a solid cast-iron frame, X, supporting

two hard cast-iron cylinders, G and H, of different diameters, which are moved by the gear-wheels B and E, themselves moved by the pulleys C D. The upper cylinder, H, turns between movable iron wedges in slide-bars the height of which is regulated by the screws F F. Behind the cylinders is a movable hopper to receive the clay. In front is placed an open cast-iron box, O, which has one orifice turned towards the two cylinders, and the other closed by a cast-iron plate held in place

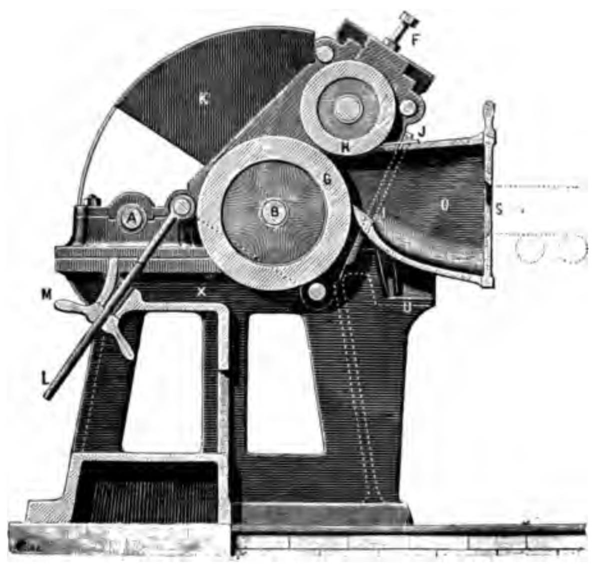


Fig. 100.—Section of a Cylinder Expression Machine (Joly).

by cotter-hooks, and pierced in the centre with a square hole, S, through which the clay passes.

This plate is called a die. At the bottom of the box A are two blades, I and J, furnished with two oval openings for the bolts which fix them to the sides of the box; these blades, called *scrapers*, can then be moved nearer to the rollers as they wear away.

The prism of clay when it issues is received on a table furnished with rollers and called the cutting-table. We shall give a description of this in a special chapter.

The machine works as follows: the clay introduced into the

hopper, K, is drawn along by the cylinders, which, in consequence of their difference of diameter, crush and blend it. It accumulates in the space O, and is gradually compressed there. When the pressure is sufficient, it issues by the opening, S, in the form of a regular prism, which is cut up on the table.

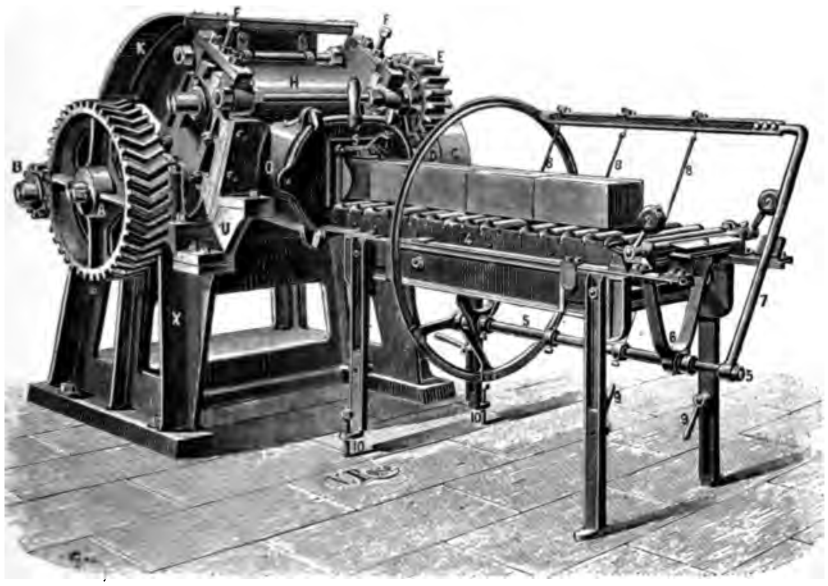


Fig. 101.—Machine with Expression Cylinders (Joly).

All cylinder machines are based on the same principle, the dimensions and shape of the parts only being different. Thus the Joly machine is so constructed that it can also be used for pottery (Fig. 575). If the size of the machine be reduced, it can be worked by hand (Fig. 102), but we cannot recommend this unless unavoidable.

The model in Fig. 103 is the preceding machine made stationary; this simplifies the construction and consequently reduces the price (see table, p. 146).

When the propelling cylinders have the same diameter, as in the Sachsenberg (Fig. 104) and Groke (Fig. 105) machines, they have a different speed, so that friction may be produced for pugging the clay and driving it towards the die.

The Jäger machine (Fig. 106) possesses the same parts as

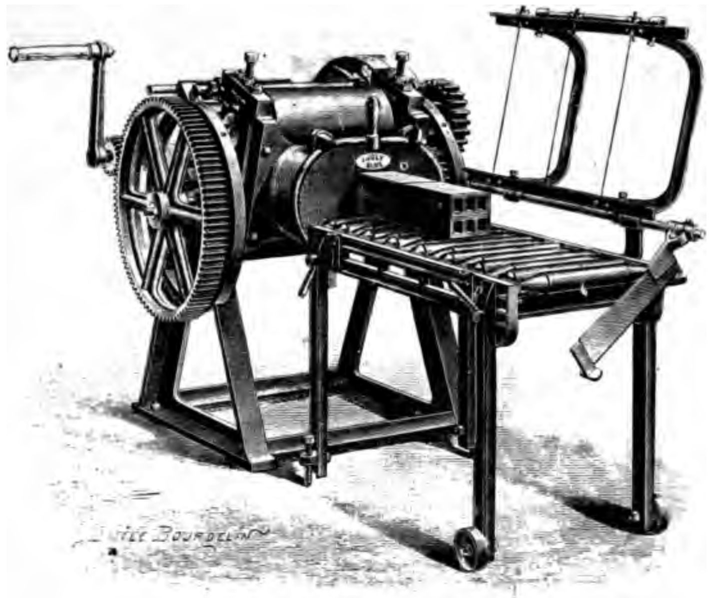


Fig. 102.—Hand Cylinder Machine with Movable Frame (Joly).

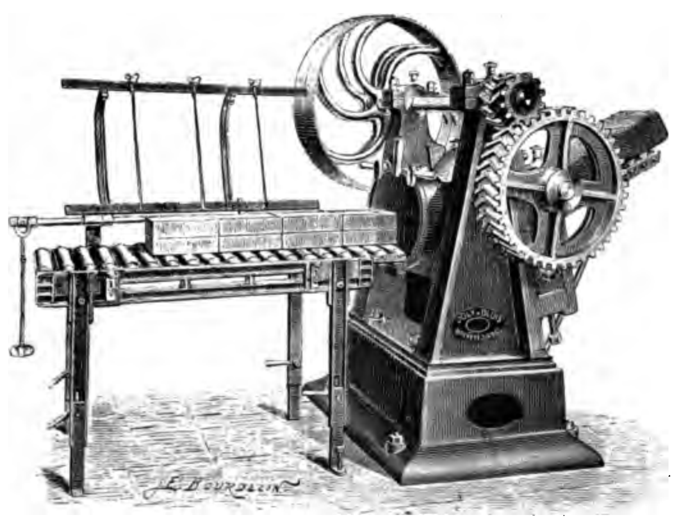


Fig. 103.—Cylinder Machine with Fixed Frame (Joly).

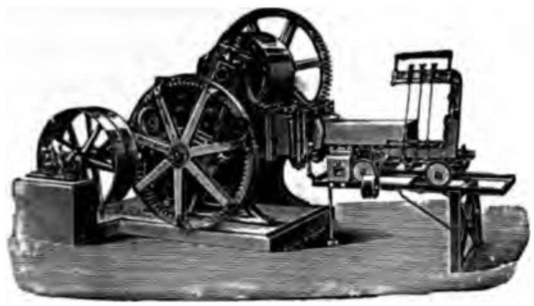


Fig. 104.—Cylinder Expression Machine (Sachsenberg).

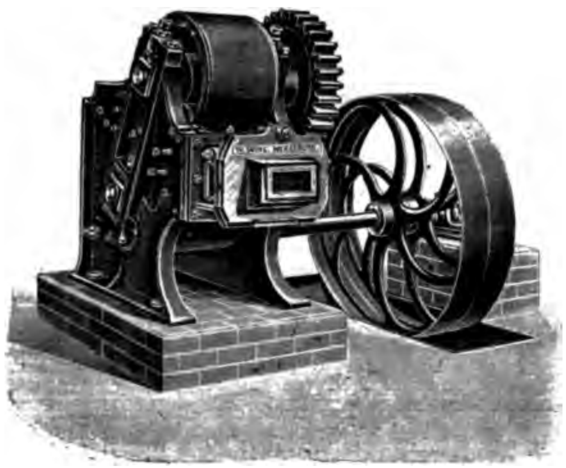


Fig. 105. Cylinder Expression Machine (Groke).

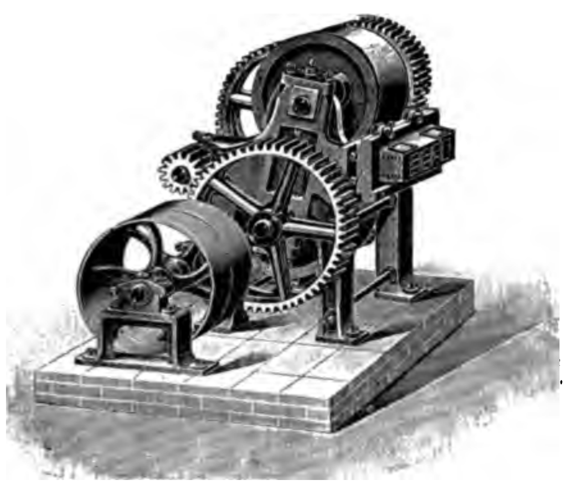


Fig. 106.—Cylinder Expression Machine (Jäger).

the foregoing machines, but the space in which the clay is compressed is reduced to a minimum; the clay passes straight to the die from the cylinders. These latter are sometimes fluted instead of smooth, the flutings being angular or straight like those of the Johnson machine (Fig. 107). This machine has

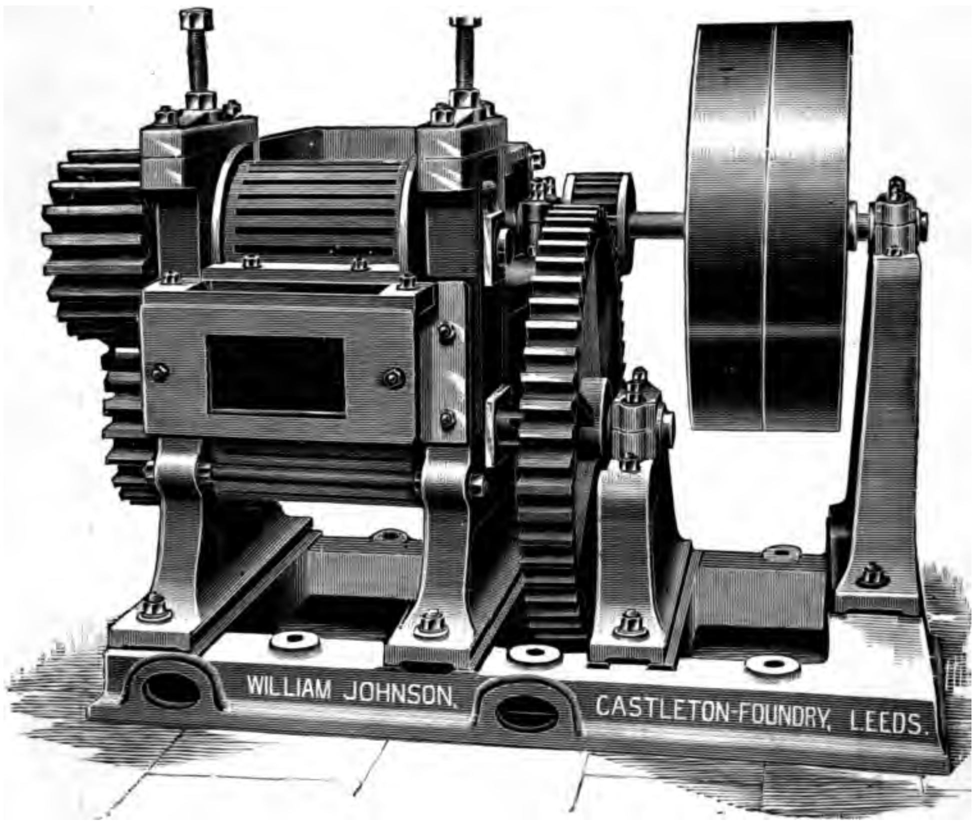


Fig. 107.—Expression Machine with Fluted Cylinders (Johnson).

three rollers: two to compress the clay and placed one over the other; the third passes the clay to the two first.

Cylinder Machines combined with Pug-mills.—Except in a few cases it is preferable to submit the clay to a previous pugging before sending it to the cylinder machine. Thus a good installation is one in which the two machines are so arranged that the clay passing from the pug-mill is at once absorbed by the moulding machine.

Fig. 108 represents an installation of this kind composed of a pug-mill (Fig. 60) and the cylinder machine of Fig. 101.

Another installation of the same kind (Fig. 109) combines the pug-mill of Fig. 62 and the machine with propelling cylinders of Fig. 104.

Any kind of clay can be treated by an installation of this type, provided it is friable and contains no very hard particles which would require special crushing. The mixture of rich and

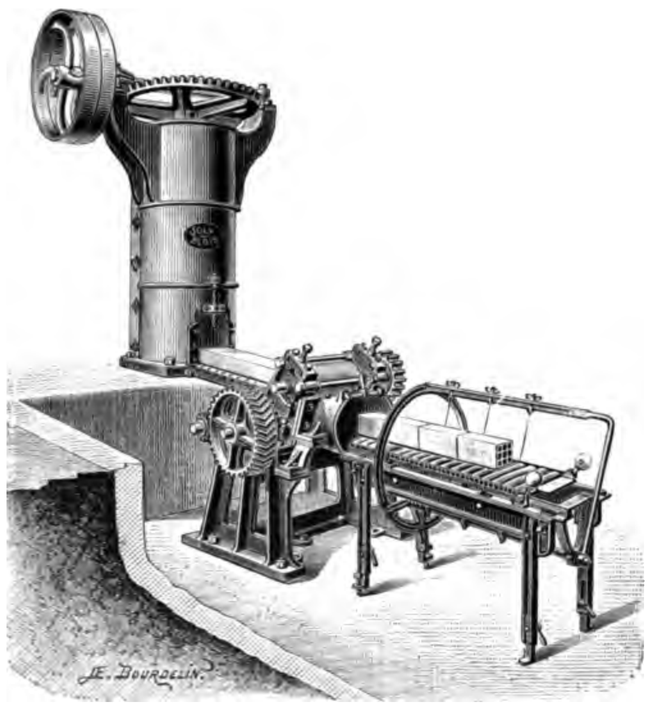


Fig. 108.—Cylinder Expression Machine combined with Pug-mill (Joly).

shortening clays is carried out in the pug-mill, as are any other mixtures required.

Brick-making Machines with Pug-mill and Screw Expresser.—We stated, when speaking of pug-mills, that the clay underwent, by the action of the knives in those machines, a certain pressure which drove it through the orifice of issue, this expulsion being facilitated by the presence near that orifice of screws of various forms.

This being so, if the orifice is provided with a die and the parallelopiped of clay is received on a cutting-table, we have a brick-making machine. This is a most simple machine, giving good results with clays which are free from all foreign substances, and easily worked. These machines are called vertical or horizontal according to the position of the pug-mill.

Machines with Vertical Pug-mill.—*A*. WORKED BY ANIMAL POWER.— These machines do not differ from pug-mills of the same type (see p. 74). The orifice of issue is provided with a

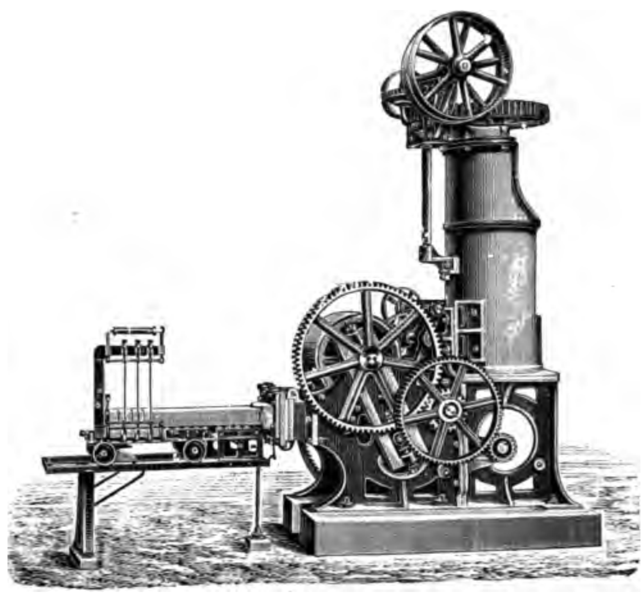


Fig. 109.—Cylinder Expression Machine combined with Pug-mill (Sachsenberg).

die, and a cutting-table is joined to the machine. Theoretically any pug-mill can be made into a brick-making machine; practically, as we said above, special clays are required to get good results under these conditions.

Fig. 110 represents a Whitehead pug-mill with two issues, transformed into a brick-machine, and worked by a horse-gear fixed to the shaft of the mill. In this way power is more economically applied, but it must not be forgotten that the supply of clay and removal of bricks are rather difficult in these machines on account of the horses.

B. WORKED BY STEAM.—These are the same machines but more powerful and of greater output.

In the Whitehead machine (Fig. 111) the gearing is separate, but there are simpler arrangements in which the pug-mill supports the driving-gear.

Screw Machines.—These consist of a horizontal pug-mill, in which are screws of various shapes and sizes. At the end of the pug-mill is placed the die through which the prism of clay passes. Above are usually fixed one or several rollers for different purposes; some serve to supply clay regularly to the screws and for crushing the hard portions in it. The others, when used, are true rolling machines like those we have

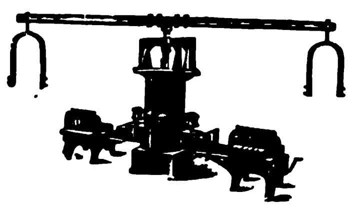


Fig. 110.—Vertical Pug-mill worked by Horse-gear.

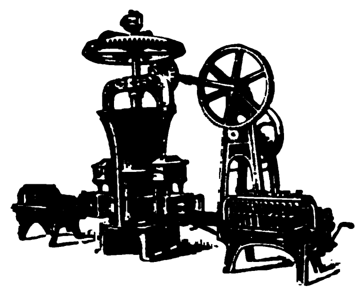


Fig. 111.—Vertical Pug-mill worked by Steam.

described under the head of Preparation of Clays. They are used for clays which require to be crushed before being pugged.

The working of the screw machines is easily understood. The clay comes to the pug-mill in a regular and continuous stream, is seized by the blades of the screws, mixed, triturated, divided, and finally driven towards the outlet as would be the nut of a turning screw fixed at its two ends. The treatment of the clay is more or less severe according to the dimensions of the mill. In the French machines the screws are two in number and turn in opposite directions.

In order to simplify the description of the numerous screw machines, which are, besides, all based on the same principle, we shall classify them according to the number of cylinders attached to them. We shall have then—

1. Simple screw machines.
2. Screw machines with distributing cylinders.
3. Screw machines with rollers and distributing cylinders.

1. SIMPLE SCREW MACHINES.—These are not desirable, as they can only treat pure clays or those having already undergone preliminary working. Moreover, they have to be fed by hand,

Fig. 112.—Simple Screw Machine (Jäger).

as, having no feeding cylinders, the clay is not drawn up by the screws; therefore their use is not recommended.

2. SCREW MACHINES WITH ONE OR TWO DISTRIBUTING CYLINDERS. — To make sure of regular distribution and continuous flow of clay to the pug-mill, it has been found advisable to join to it one or two cylinders whose rotation, opposite in direction to that of the screws, assures a constant supply.

The arrangement of these machines is similar to that of the preceding ones. The gear which transmits motion to the screws

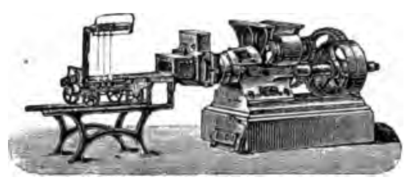


Fig. 113.—Screw Machine with a Distributing Cylinder (Laeis et Cie.).

is fixed on the framework itself of the machine (Fig. 113) or separate from it (Fig. 114).

When there are two cylinders, as is usually the case, they crush small stones and lumps which may be contained in the clay, without, however, producing as thorough effects as rolling machines specially constructed for that purpose.

Fig. 115 represents a machine with two distributing cylinders

whose axes are in the same plane. It is fixed on a cast-iron framework in such a way that the die is on the level of the

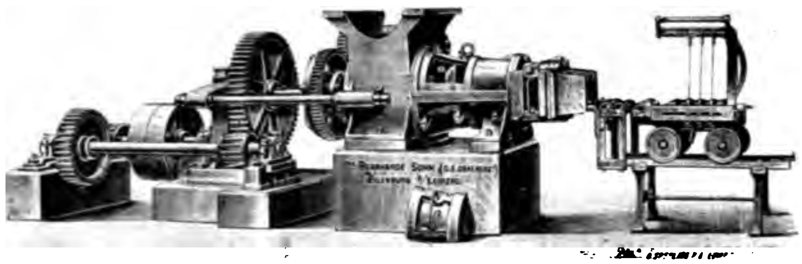


Fig. 114.—Screw Machine with a Distributing Cylinder (Bernhardi Sohn).

cutting-table. At the foot of the framework in the figure may be seen a die with water-face so that the brick may come out flat.

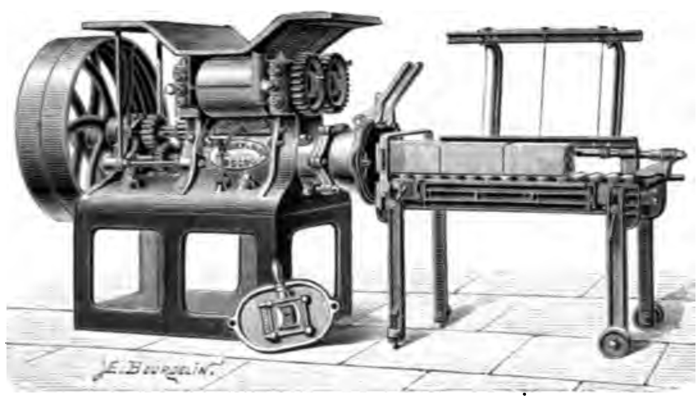


Fig. 115.—Machine with two Screws and two Distributing Cylinders (Joly).

The Boulet machine (Fig. 116) does not sensibly differ from the last.

The Lacroix machine (Fig. 117) is also similar to the preceding ones. In the figure one of the workmen is throwing clay between the cylinders while the other cuts off the hollow products as they come from the die.

In other machines, notably those made by the Johnsons (Fig. 118), a special arrangement for bringing up the clay is observed. At the side is placed a windlass worked by the machine and set in motion by means of a gear lever which is

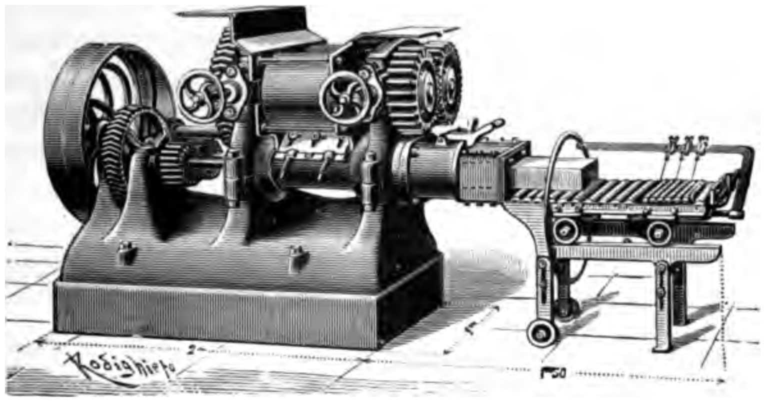


Fig. 116.—Screw Machine with two Distributing Cylinders (Boulet).

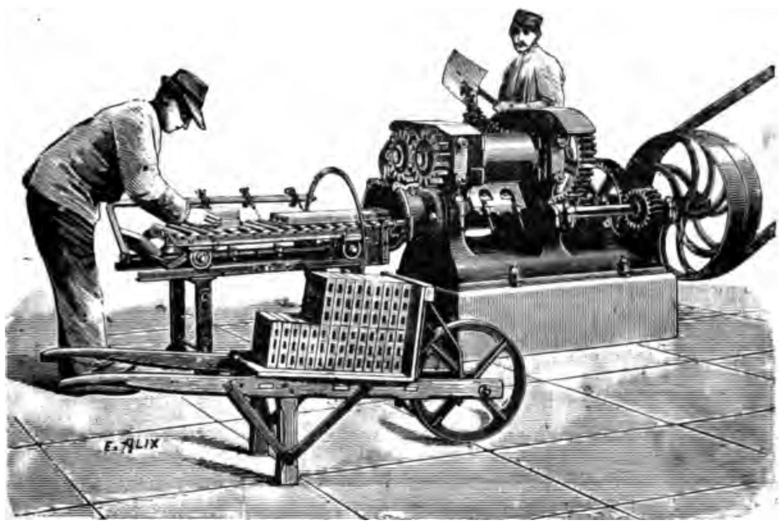


Fig. 117.—Screw Machine (Lacroix).

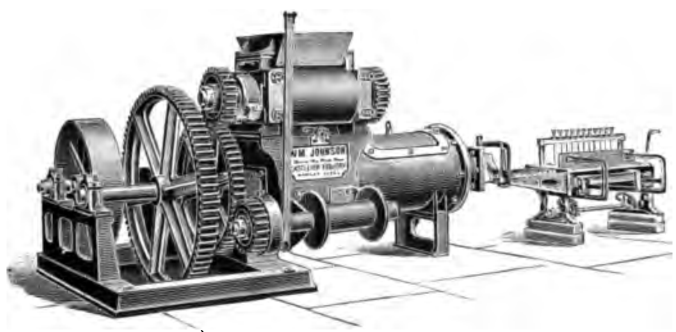


Fig. 118.--Machine with Screws and Distributing Cylinders, furnished with a Windlass (Johnson).

seen in front of the machine. This windlass brings up the waggons full of clay close to the hopper of the machine by means of a chain; then they have only to be overturned.

The distributing cylinders are arranged in different ways;

Fig. 119.—Screw Machine with Distributing Cylinders (Börner).

sometimes their axes are in the same plane (Figs. 115, 116, 117), sometimes they are not (Figs. 119, 121).

It may be seen from the figures that the dies have different shapes and appearance; we shall refer to them in a

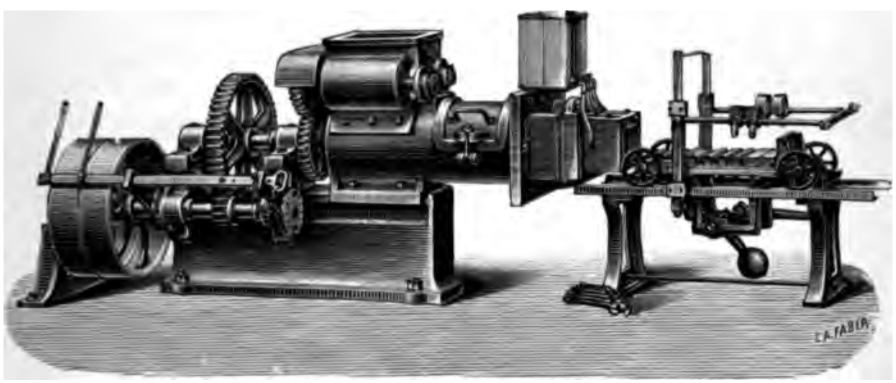


Fig. 120.—Screw Machine with Distributing Cylinders (Jacobi).

more detailed manner in the paragraph relating specially to them.

In certain powerful machines, the output of which is considerable, the pan of the pug-mill is in two parts joined by bolts. This arrangement facilitates cleaning (Figs. 122, 123) and taking to pieces.

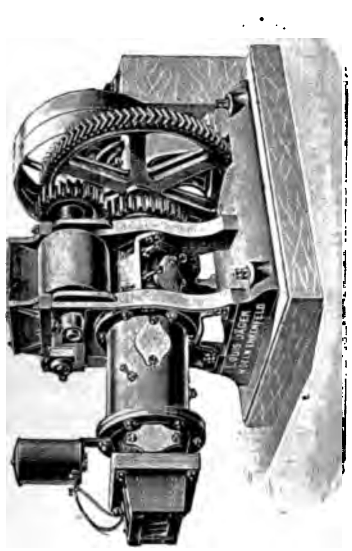


Fig. 121.—Screw Machine with Distributing Cylinders (Jäger).

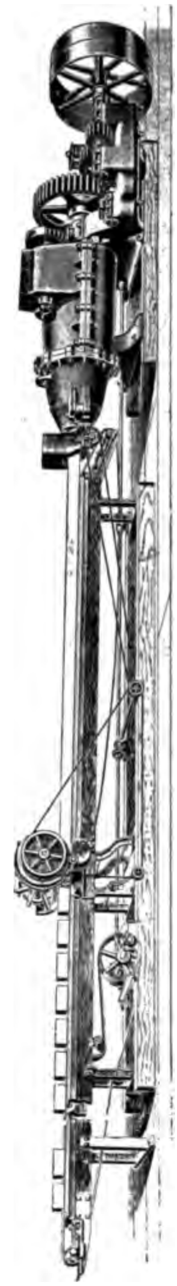


Fig. 122. Screw Machine with Distributing Cylinders (Penfield).

Fig. 122 represents a strong American machine producing 5000 to 8000 bricks an hour with a motive force of 75 horse-power.

The Chambers machine (Fig. 123) is similar to the last-named in arrangement and production.

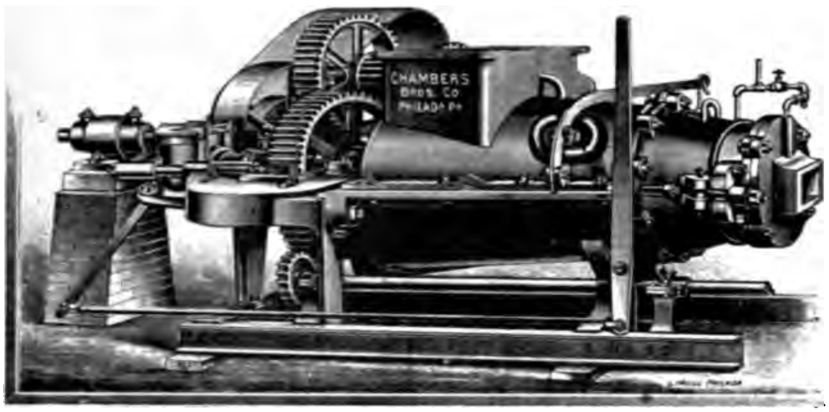


Fig. 123.—Screw Machine (Chambers Brothers).

Instead of cylinders, cones can be used, and act as rollers as well as distributors.

Screw Machines with Rollers and Distributing Cylinders.—We have stated that the distributing cylinders of screw machines,

Fig. 124.—Screw Machine with Distributing Cones (Jager).

the principal aim of which is to stuff the pan of the pug-mill with clay, could to a certain extent act as crushers. But when the crushing has to be severe it is preferable to substitute a pair of conical (Fig. 124) or cylindrical rollers (Fig. 125) which are placed above the distributing cylinder or cylinders. These

rollers are worked direct from pulleys (Figs. 125, 128) or else receive their motion from the gearing of the machine by means of cog-wheels (Fig. 126).

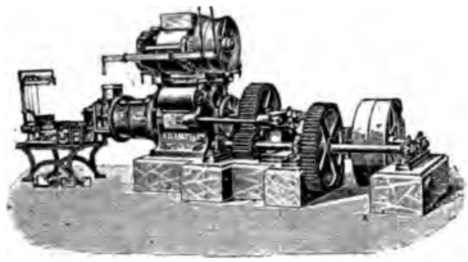


Fig. 125.—Screw Machine with Rollers and Distributing Cylinders (Laeis et Cie.).

If the clay is difficult to hold, cylinders with points are used like those we have described (Fig. 27).

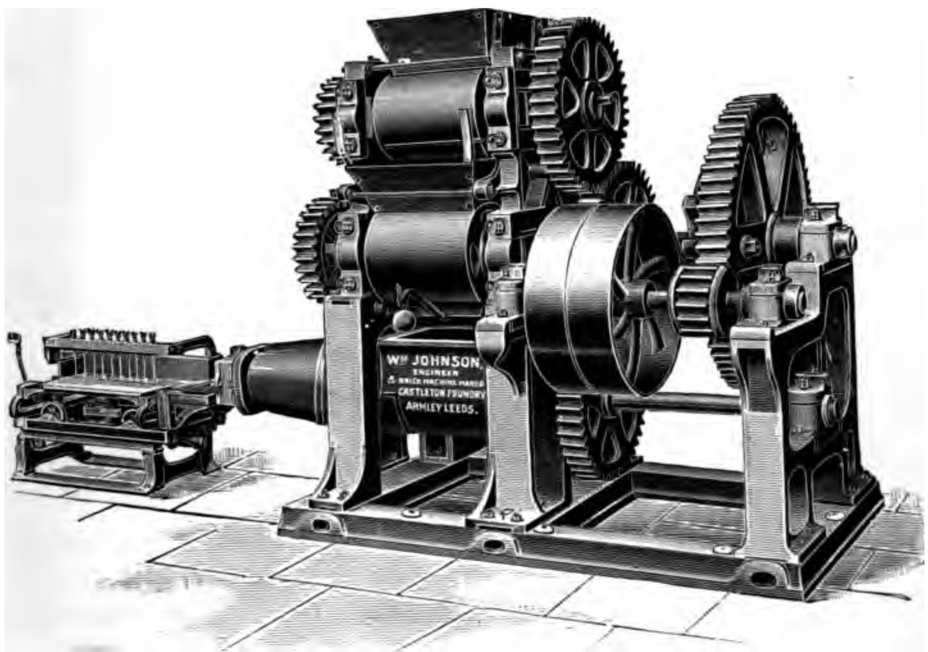


Fig. 126.—Screw Machine with Rollers and Distributing Cylinders (Johnson).

The machine represented in Fig. 127 is so made. One or two pairs of rollers, cylindrical, conical, or fluted, are placed over it, according to the nature of the clay to be treated.

Finally, if there is a difficult mixture to be made, or a perfectly homogeneous paste is desired, a pug-mill is added to the screw machine.

Fig. 129 shows an installation of this kind.

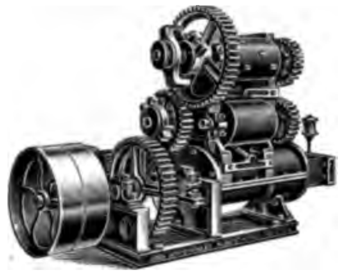


Fig. 127.—Screw Machine with Rollers, Distributers, and Cylinders with Points (Whitehead).

As can be seen from the numerous figures above, which do not by any means represent all the types of machines constructed, the manufacturer of pottery has a large choice, which cannot

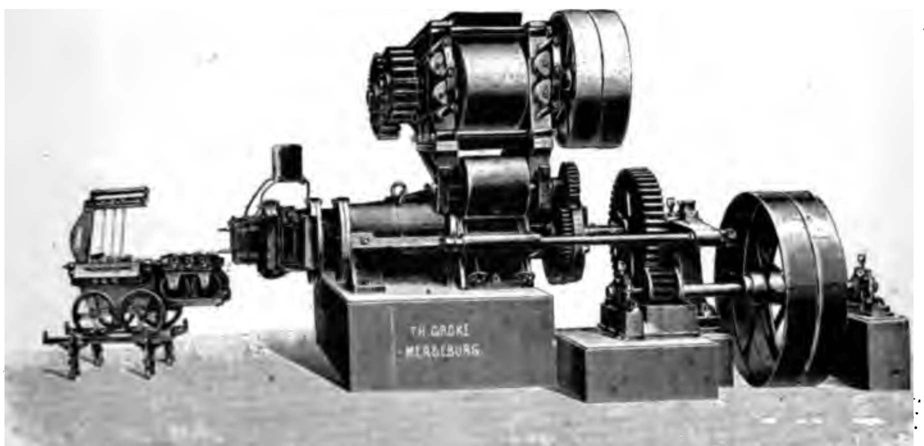


Fig. 128.—Screw Machine with Rollers and Distributing Cylinders (Groke).

fail to embarrass him. The composition of the clay to be treated, and the way in which it is to be treated according to the articles to be made from it, are the only things which should influence him; in the last resort experience is the only guide.

Screw machines are intended for treating clay in the state of a semi-firm paste, the most suitable state for getting the maximum of output with the minimum of motive power.

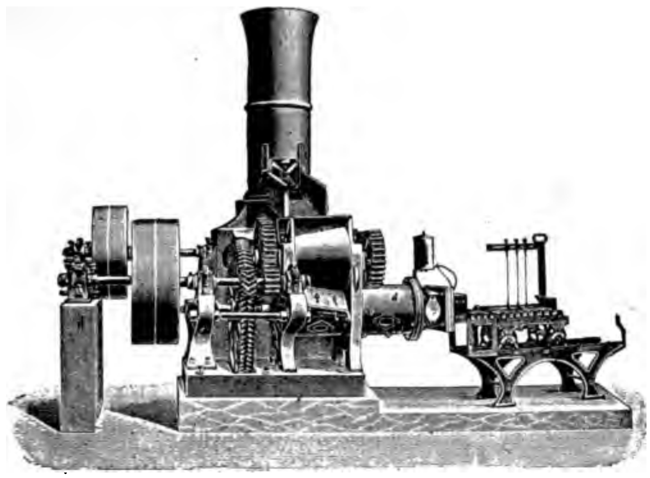


Fig. 129.—Screw Machine with Distributing Cones and Vertical Pug-mill (Jäger).

Piston Machines.—These machines are intended for treating clay when in a state of firm paste. It will be understood that the firmer the clay to be worked upon is, the greater is the effort required to force it through the die. Hence machines with propelling cylinders or pug-mills with expression screws are unsuitable for this kind of work. They are replaced by machines which compress the previously pugged clay into boxes with a piston.

One of the ends of these boxes forms a die. The piston has an alternating motion, therefore the production is not continuous, but in order not to lose the return motion the machine is double and furnished with two cutters. In machines with large output like that of Fig. 37 the feeding is done by hoppers into which the clay is thrown during the return journey of the piston.

In small machines (Fig. 564) the clay is placed in two boxes, the upper part of which form lids: while one is emptied under the pressure of the piston the other is being filled with clay.

Large piston machines are called "galettières"; they are used for the preparation of slabs for tiles; the others are specially

employed for the preparation of hollow products and especially pipes. We shall describe them when we speak of the manufacture of these.

II. *Description of Dies.*

Dies are the orifices by which the clay escapes when compressed by the motion of the screws or cylinders. These dies are movable, and are fitted to the machines either by collar-bolts, or nuts and bolts, or any other means. As the shape of the orifice is variable, it may be seen at once that brick-machines working by expression can make bricks of any dimensions or shape. Let us consider how clay issuing from a die behaves. According to Schlickeysen (experiments made in 1856)—

1. Well prepared and ductile clay driven vertically through a rectangular orifice in sheet-iron with narrow walls, comes out without cohesion; the prism opens out at the four angles as far as the centre.

2. If the thickness of the walls is increased so as to make a cylindrical pipe, the prism acquires cohesion, but breaks perpendicularly at short intervals.

3. If the thickness of the walls, or the breadth of the pipe, is still more increased, the prism of clay then splits into two in a plane passing through the angle of pressure. This separation is due to a slackening of the speed of the exterior particles, due to their friction against the sides of the pipe. The two pieces curve outwards. If this effect is produced in consequence of the thickness which must be given to the face-plate, the influence of friction can be reduced by piercing conical holes from the outside to the inside, which diminishes the surface of friction.

4. If the piping is conical from inside to outside, so that the largest section is towards the machine, the cohesion of the prism is increased, but the surface is covered with flutings and the edges are jagged.

The effects above described are very variable according to the richness of the clay. With a paste of a proper degree of

dampness and plasticity there is no tearing at the angles when it comes through the die. If the clay is too damp, or if it changes from less to more moist, the prism is deformed and increases in volume as it issues. Finally, thin clays require special dies called hydraulic.

To summarise, what must be avoided is the friction caused by the walls of the piping, especially at the angles, which tends

Fig. 130. Fig. 131.

Fig. 132.

Fig. 133.

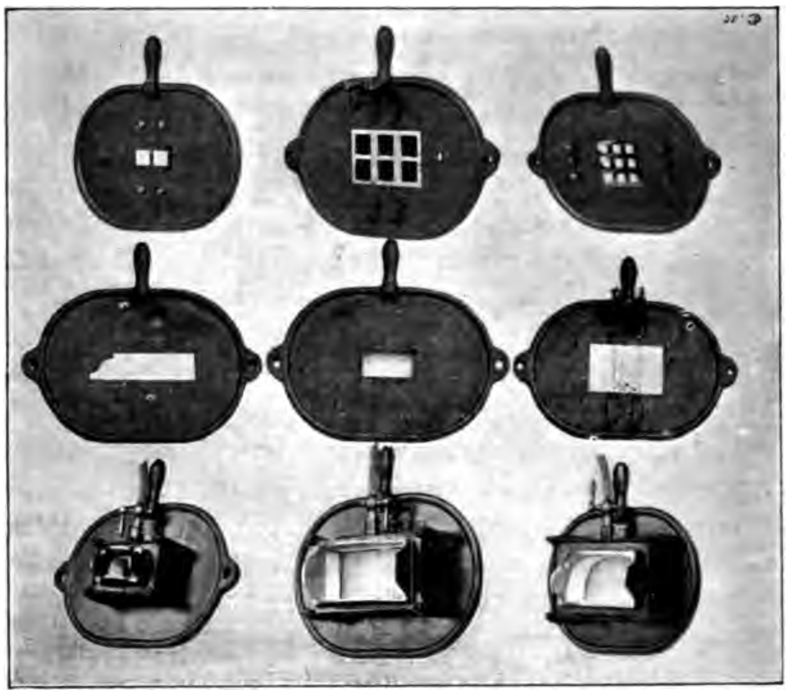


Fig. 134.

Fig. 135.

Fig. 136. Fig. 137. Fig. 138.

Figs. 130-138.—Various Dies.

to produce a slackening of speed of the outer molecules as compared with that of the inner ones. If this slackening occurs the prism of clay undergoes one of the above-mentioned deformations. This inconvenience is less to be feared with rich clays, which glide more easily; it is otherwise with thin clays, and for them hydraulic dies are required (Figs. 136, 137, 138). Inside a hydraulic die, on the four faces, is placed a pervious skin

fitting closely to the prism of earth. This skin is surrounded by an empty space bounded by the sides of the die. This space is furnished with a pipe to which is attached a tap communicating with a water-conduit or reservoir frequently placed above the machine over the die (Figs. 120, 121, 124, 129). The water passes into the die, percolates through the skin, and lubricates the clay, thus facilitating its expression. The flow of water is regulated by the speed of the prism.

The shape of dies varies with the maker, as can be seen by an examination of the different machines we have described (Figs. 100 to 128); but in all of them arrangements are made to ensure that the prism shall issue with smooth faces and clear-cut edges. We give sketches of some dies for hollow bricks (Figs. 130, 132, 134), for solid bricks with water-face (Figs. 136, 137, 138) or without water-face (Figs. 131, 133, 135). When several thicknesses of brick are to be expressed, well stretched threads are placed in front of the die and divide the prism of clay (Figs. 130, 135). The tube of the die has the dimensions and shape (Figs. 133, 138) of the brick to be manufactured. In calculating these dimensions, allowance must be made for the contraction which the clay will undergo in drying and firing; 10 per cent. is usually allowed for semi-firm pastes.

Several cases present themselves according to the position in which the brick comes out.

1. The prism forms one brick.

A. Flat (Figs. 131, 132, 136), $0.105 \times 0.06 = (x - \text{contraction})\ (y - \text{contraction})$.
B. Up on edge (Figs. 137, 138), $0.220 \times 0.105 = (z - \text{contraction})\ (x - \text{contraction})$.

The dimensions of the die will then be found by—

$$x - \frac{x}{10} = .105 \qquad \therefore\ x = .116$$

$$y - \frac{y}{10} = .06 \qquad \therefore\ y = .066$$

$$z - \frac{z}{10} = 0.22 \qquad \therefore\ z = .244$$

2. The prism forms several bricks—

A. Flat (2 bricks): $(0.105 \times 2 \times 0.06) = (x^1 - \text{contraction})\ (y^1 - \text{contraction})$.
B. Up on edge (3 bricks) (Figs. 130, 135): $(0.105 \times 0.06 \times 3) = (x^1 - \text{contraction})\ (y^1 - \text{contraction})$.

The dimensions are therefore found by—

$$x^1 - \frac{x^1}{10} = .21 \qquad \therefore x^1 = .233$$

$$y^1 - \frac{y^1}{10} = .06 \qquad \therefore y^1 = .20$$

It must be noted that bricks being placed on edge in firing contract more in height than in the other two dimensions; thus, we must increase x but diminish y and especially z. For example, we shall take—

$x = .120$ instead of $.116$
$y = .065$,, ,, $.066$
$z = .240$,, ,, $.244$

Whenever it is possible to judge by experiments made with moulding clay, we should not fail to do so; they give the most accurate information.

III. *Description of Cutting Machines.*

These are divided into two classes according as they are worked by hand or automatic. In the first class we shall make a distinction between cutting machines with trolleys and those without, also between those cutting obliquely and those cutting perpendicularly.

- 1. Hand-cutters
  - *A.* With movable threads
    - (1) Simple
    - (2) With trolley
      - (*a*) Cutting obliquely.
      - (*b*) Cutting perpendicularly.
  - *B.* With fixed threads
- 2. Automatic cutters.

1. **Hand-cutters.**—*A.* WITH MOVABLE THREADS.—The principal parts of these machines are: a framework, rollers, wire-carrier, and a stop-pallet: we shall describe them in turn.

The *Framework* is composed of two cast-iron brackets joined by cross-pieces (Figs. 140, 141), or of a cast-iron frame resting on four legs (Figs. 101, 102, 103), or simpler still, of a frame resting on one support and one leg (Fig. 104). The four legs generally have adjustment screws (Figs. 101, 140, 142), so that

the table can be raised at will and placed in a perfectly horizontal position.

The *Rollers* are of wood covered with chamois leather, or of plaster; this is because certain clays adhere to the plaster and slip on the leather. The rollers are movable about an iron axis whose ends rest on notches made in the sides of the framework. The rollers made of wood covered with chamois are supplied all ready mounted by the makers; when the leather is worn out it is renewed.

To make the plaster rollers, a bronze mould (Fig. 139) is used, divided into two parts, which are slightly conical in exterior shape, and are held together by two rings. The inside of the two parts is greased, they are fixed together by means of the rings, and the iron axis is placed through the middle, one end resting in a hollow in the lower part of the mould. The axis is held quite vertical, and plaster in a fairly liquid condition is poured round it. When it becomes solid it is taken out of the mould and dried. The plaster rollers get quickly worn out, but it is easy to remake them; the cost of plaster is small.

The *Wire-carrier* consists of a frame of variable shape, across which are stretched steel wires of excellent quality. One end of these wires is fixed to a socket movable on one of the sides of the frame; the other end is fixed to a screw and hook fitted with a *fluked* nut. A special arrangement allows these hooks to slide along the rod which holds them. They are fixed by means of the nut. These wires can therefore be moved at will and placed at any desired distance from one another: care must of course be taken that they pass between the rollers. This wire-carrier swings on an axis fixed to the frame of the machine (Figs. 101, 140).

Stop-pallet.—This is a movable piece placed at the end of the trolley; its object is to fix the thickness of the first brick, the thickness of the following ones being given by the distance between the wires. The work of this pallet is very important, for on it depends a good or a bad division. In certain cutting machines its motion is linked to that of the wire-carrier (Fig. 142); in others it is independent of it (Figs. 101, 102, 140).

(1) **Simple Cutting Machines.**—We shall describe a small cutting machine (Fig. 102), which gives good results in cutting

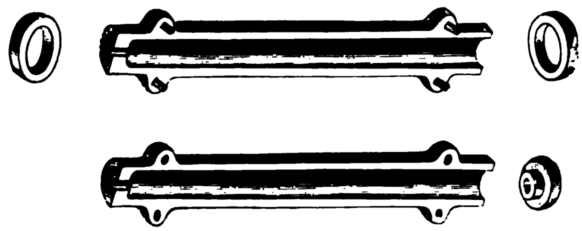


Fig. 139.—Bronze Mould for making Plaster Rollers (Chavassieux).

bricks, especially hollow bricks, in a flat position. It is composed of the same parts as the previous ones, but has no trolley.

The pallet is movable round a cylindrical rod; it is kept in position by two rings fixed by bolts to the rod itself. On the rod also slides the wire-carrier; this is fixed by bolts pressing on the rod as in the case of the movable rings. The distance between the pallet and the first wire is equal to that between the wires. In the ordinary position this pallet rests on the rollers (3, Fig. 140), and, by sliding the rod through two sockets fixed to the framework, it may be dropped on to a stop; it is then in the position of Fig. 102. To cut, the pallet is raised, the wire-carrier is pushed to the left, and the pallet is allowed to fall upon the rollers. When the prism of clay reaches it, the wire-carrier is quickly lowered, and to raise it again a slight pressure to the right is exerted in order to follow the motion of the clay, and bring the wires back through the same path. As soon as the wires are freed, the frame is pushed to the right; the pallet follows this motion, and falls on its stop. The cut bricks are taken away, the pallet is replaced on the rollers by pushing the wire frame, and the same process is repeated.

The cutter represented in Fig. 140 is similar in arrangement to the preceding one: it carries at the entrance a wire the use of which is to cut the prism horizontally in the case, in which it has the thickness of two bricks.

(2) **Trolley Cutting Machines** consist of the same parts as the preceding ones, but a certain number of rollers are mounted on a trolley which runs by means of flanged wheels on rails

forming the edges of the frame. Sometimes these flanged wheels are inside the frame and are consequently invisible, sometimes they are visible. In other cutting machines (Fig. 142) the trolley is double.

According to the manner in which the wire attacks the prism of clay, we shall have—

(*a*) *Angular Trolley Cutting Machines.*—These machines act as

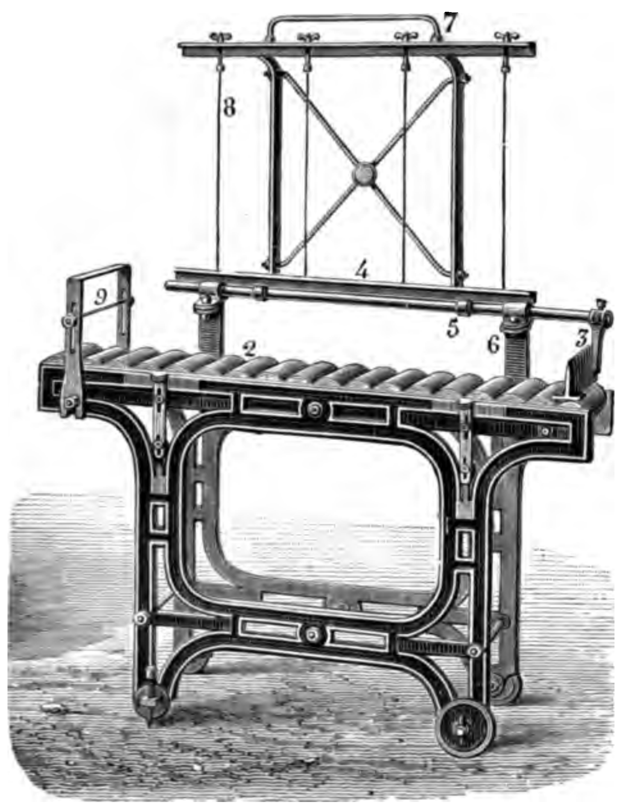


Fig. 140.—Small Cutting-table (Joly).

follows. The movable trolley being pushed against the two rollers of the fixed frame, and the stop-pallet being raised, the prism of clay advances over the rollers, which turn and thus facilitate its motion. Having reached the pallet, it draws on by its motion the trolley, which begins to move along on its wheels; it is then that the wires are brought into use.

In the Joly machine (Fig. 101) the wire-carrier swings on one of its sides 5, 5. The stop-pallet is fixed to an axis fitted with two counterpoises which keep it raised. In order to prevent the prism of clay when it strikes it from turning it over, one of the counterpoises is held with one hand, and with the other the wire-carrier is brought forward. The prism is cut; the pallet is released and falls (Fig. 101), the bricks are removed, the pallet is raised, and the trolley is pushed back again. The same movements are repeated, the wire-carrier being successively pushed backwards and forwards. In those cutting machines where the wire frame is fixed to the trolley (Fig. 141) the

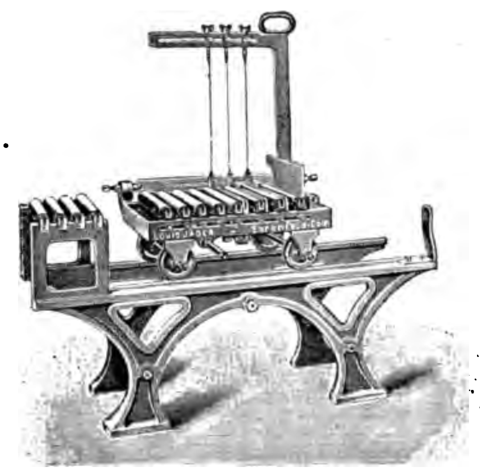


Fig. 141.—Trolley Cutting-table, cutting at an Angle (Jäger).

motion of the former is connected with that of the pallet, which, during the operation of cutting, is held by a piece fixed to the arms of the wire frame, and released as soon as the cutting is done.

The Groke cutter (Fig. 142) has two trolleys; the wire frame has a spring and returns automatically to its first position.

We call the preceding cutters angular because the wires attack the prism at a certain angle: others are made in which this attack takes place perpendicularly to one face of the prism; such are—

(*b*) *Perpendicular Trolley Cutting Machines.*—The wire frame,

which is placed parallel to the rollers, is guided in its motion by two rods fixed to each side of the trolley. An arrangement of levers allows of its being brought down on to the prism of clay. In another system (see Fig. 120) the wire frame is fixed to the framework of the machine and not to the trolley.

Fig. 142.—Trolley Cutting-table, cutting at an Angle (Groke).

The Börner (Fig. 144) cutting machine is arranged for making special corner cuts for arch bricks; it also cuts perpendicularly. It can be regulated to all dimensions, as the wires run between guides which can be moved at will.

B. FIXED WIRE-CUTTERS.—In the preceding machines the wires are movable and the prism of clay is fixed; in the following ones the arrangement is reversed. The movable table is preceded by rollers, which facilitate the gliding motion of the clay. When the latter has attained a sufficient length (8 to 10 bricks) it is cut by a single wire, then the piece is pushed back from the wires against a square board. By means of the lever seen on the left in Fig. 146, and which is moved forward, the block meets the stretched wires and is divided into regular pieces, while the bricks so formed are placed on a movable tray, which has only to be taken up and placed on the barrow without

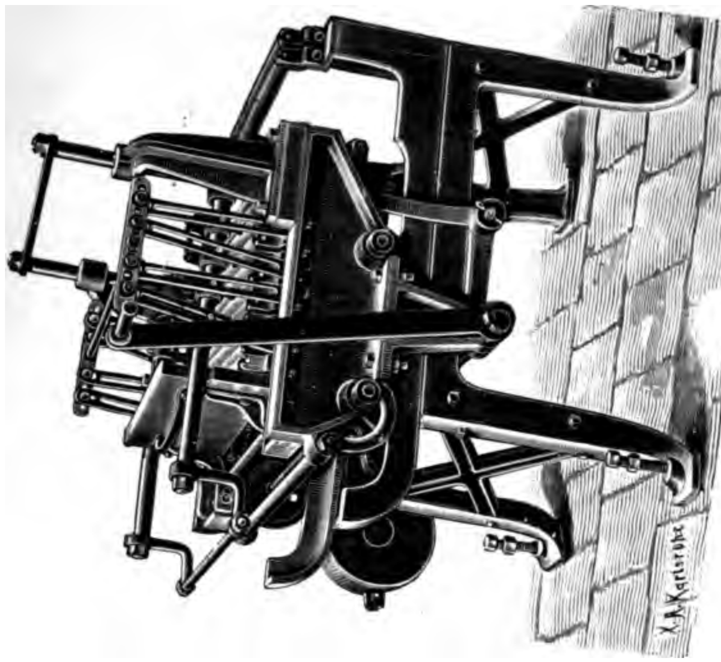


Fig. 144.—Special Trolley Cutting-table (Börner).

Fig. 143.—Perpendicular Trolley Cutting-table (Groke).

the bricks being touched (Figs. 118, 126). Fig. 145 shows the arrangement of the rack-work and toothed segment, which give the backward and forward motion to the table; at the left is seen the square stop which checks the end of the prism. In these machines there is always a certain waste, owing to the difficulty of so cutting the prism that it may contain an exact number of bricks. The excess of clay beyond the last wire is useless, and must be thrown back into the machine.

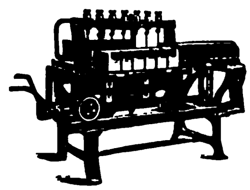


Fig. 145. Cutting-table with Side Discharge (Whitehead).

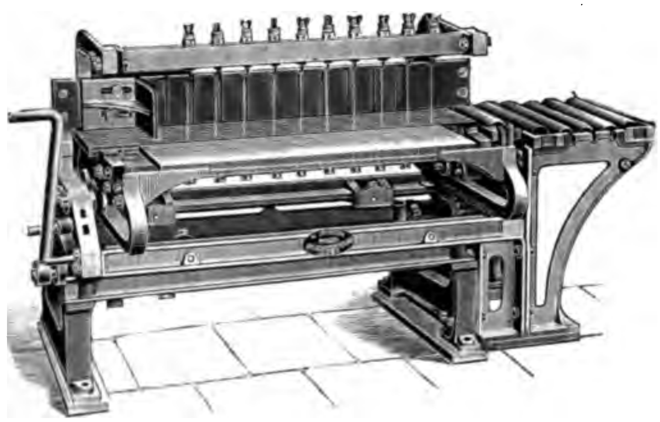


Fig. 146.—Cutting-table with Side Discharge (Johnson).

2. **Automatic Cutting Machines.** — It has naturally been thought that the motion of the prism of clay might be utilised to work a cutter which would require no separate mechanism. It is on this principle that automatic cutters are based.

A small machine of the kind is manufactured by Chavassieux, and is shown in Fig. 147. The clay issues on a special endless band which rests on rollers and passes over drums. The clay by its weight and adhesiveness draws the band on in its motion,

and the band turns the drum round as it passes. The rotation of the drum is communicated by means of a pulley and belt to a kind of star-shaped wheel whose branches are joined by the steel wires which cut the clay. The length of the arms of the wheel and the position of the wires are calculated according to the dimensions of the bricks required.

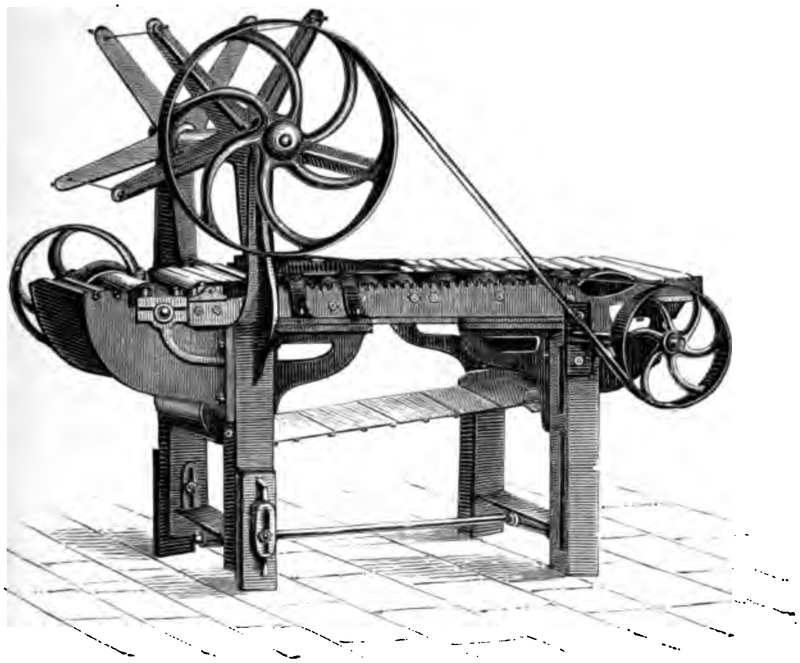


Fig. 147.—Automatic Cutting-table (Chavassieux).

We give (Figs. 148, 149, 150, 151, 152) sketches of automatic cutting machines of American make. The complicated mechanism of these machines may be seen. The arrangements made for assuring a quite perpendicular cut will be noticed: in its passage under the wheel the prism of clay is bent in order to counteract the curvature of the cut caused by the rotation of the wire, and, in order to disengage the latter when the cut is made, the endless band does not pass over the place where the cutting is done; there is a system of drums for the return and motion of the endless band.

In Fig. 149 the prism is seen passing under the wheel, and the

AUTOMATIC CUTTER (Penfield).

Fig. 148.

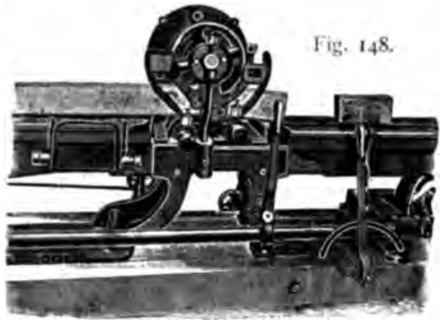


Fig. 149.

Fig. 150.

Fig. 148.—Back View. Fig. 149.—Side View. Fig. 150.—Front View.

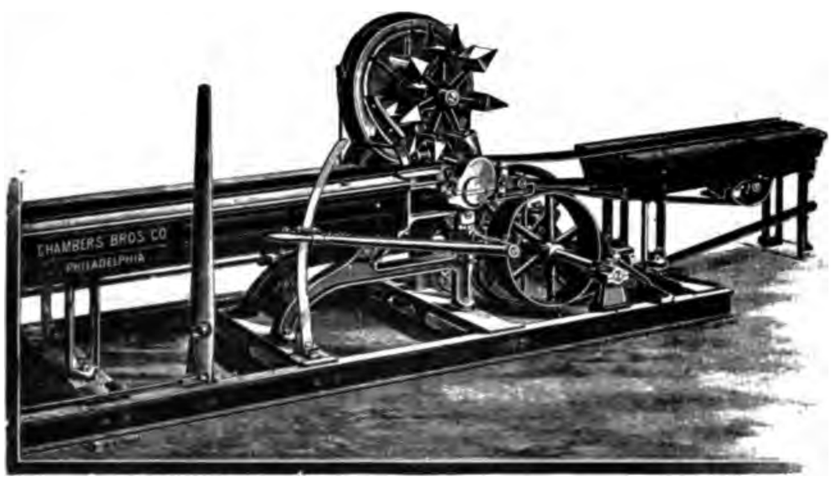


Fig. 151.—Automatic Cutter (Chambers).

cutting-wire is just about to meet it. Fig. 148 shows the operation of cutting, and Fig. 150 shows the cut bricks advancing over the front part of the table.

The Chambers cutting machine (Fig. 151) has a similar arrangement, and, as in the preceding machine, the motion of the endless band is produced by a horizontal shaft which is worked

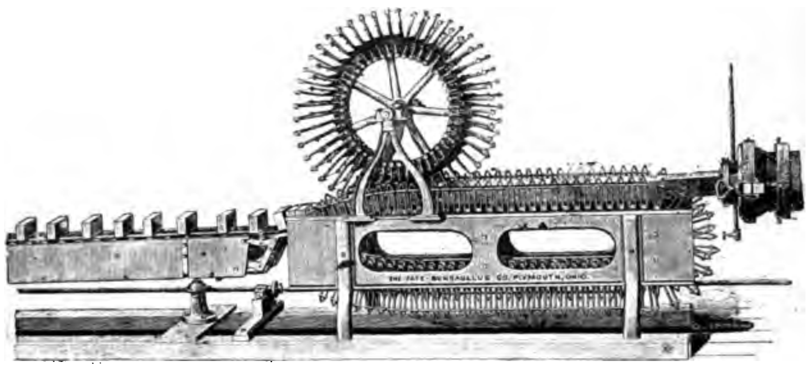


Fig. 152.—Automatic Cutter.

direct from the machine by means of cog-wheels. The great length of the tables of these cutters is necessary owing to their large output.

Instead of cutting the bricks endways, the wheel may be so arranged as to cut them lengthways. Such is the arrangement of the machine represented in Fig. 152.

[TABLE.

PARTICULARS OF THE DIFFERENT BRICK-MAKING MACHINES.

Maker.	Number of Machine.	Cylinders.		Pulleys.		Weight in Kilos.	Horse-power.	Output per Hour.	Price. in Francs.	Remarks.
		Length.	Diameter.	Dimensions in Metres.	Number of Turns.					
				PRESSES FOR MOULDING DRY CLAY.						
								Bricks.		
Boulet (Fig. 98)	...	...	...	1.00–0.11	100	6,000	2 3	800–1000	...	The output is expressed in bricks of dimensions: 0.22 × 0.11 × 0.06.
Johnson (Fig. 95)	...	...	...	0.91–0.20	220	16,250	20	2500	**16,250**	
Whittaker (Fig. 96)	...	...	...	0.75–0.12	195	6,600	4	600	**5,300**	
				MACHINES WITH PROPELLING CYLINDERS.						The prices include that of the machine furnished with a die, and of a cutter.
Groke (Fig. 105)	1	...	...	1.30–0.18	50	2500	4–5	900–1200	**2625**	With discount of 25 per cent.
	2	...	...	1.70–0.21	65	3400	6–7	1500–1800	**3060**	
Jäger (Fig. 106)	0	...	...	0.58–0.07	90	1000	2–3	400–600	**1200**	
	1	...	...	0.75–0.15	80	2200	4–7	800–1200	**2050**	
	2	...	...	0.90–0.18	165	3000	6–7	1000–1600	**2500**	
Johnson (Fig. 107)	...	...	...	0.91–0.11	130	3550	5	1500	**2500**	
Joly (Figs. 101, 103)	1	...	...	0.75–0.14	80	1600	2–3	1200–1500	**1600**	
	2	...	...	0.58–0.14	80	900	1–2	500–600	**1000**	
	1	...	...	...	...	1700	...	1200–1500	**2100**	This machine also makes pottery.
Sachsenberg (Fig. 104)	1	...	...	0.70–0.10	100	1700	3–4	800–1000	**1800**	
	2	...	...	0.70–0.12	100	2600	4–5	1000–1300	**2330**	
	3	...	...	0.75–0.15	120	3200	5–6	1300–1800	**2635**	
	4	...	...	1.10–0.16	120	5900	7–9	2400–2800	**3980**	

SCREW MACHINES WITH ONE OR TWO DISTRIBUTING CYLINDERS.

Boulet (Fig. 116)	1	...	0.25	1.00–0.11	120	...	2–4	700–1000	...	To obtain the price of machines possessing single or double rollers, it is generally sufficient to add together the price of the simple machine and that of the single or double rolling machine.
	2	...	0.30	1.00–0.11	120	...	3–6	800–1200	...	
	3	...	0.40	1.20–0.15	150	...	6–8	1500	...	
Jacobi (Fig. 120)	1	...	...	0.56–0.15	...	1,100	2–4	400–600	**1310**	
	2	...	...	0.87–0.17	...	1,500	4–6	900–1200	**1625**	
	2 *b*	...	...	0.85–0.17	...	1,800	5–8	1300–1600	**1875**	The same is the case for machines fitted with vertical pug-mill (Figs. 108, 109).
Jäger (Fig. 121)	0	0.40	0.24–0.42	0.90–0.15	120	2,750	5–8	1000–1300	**2750**	
	1	0.40	0.35–0.51	0.90–0.18	130	3,750	7–11	1400–1800	**3600**	
	1 *a*	0.40	0.40–0.55	0.90–0.18	110	5,000	12–14	2000–2600	**4250**	These machines have rollers.
	II	0.51	0.35–0.55	0.90–0.18	180	6,500	14–16	3000–4000	**4950**	Two driving gears.
	III	0.61	0.47–0.67	1.20–0.22	180	8,800	18–20	4000–5000	**6500**	,, ,,
Joly (Fig. 115)	2 *bis*	...	...	0.95–0.14	60	1,300	2–4	400–600	**1500**	
	2	...	...	0.95–0.14	70	1,500	2–6	600–1000	**1800**	
	1	...	...	1.30–0.16	75	2,400	8–10	1500–2000	**2250**	
Lacroix (Fig. 117)	1	0.42	0.40	1.00 0.11	140	3,000	6–8	1700–2000	**3200**	
	2	0.40	0.30	1.00–0.11	120	2,100	3–6	900–1200	**2500**	
	3	0.32	0.25	0.80–0.11	150	1,500	2–4	600–800	**1800**	
Laeis & Co. (Fig. 125)	0	...	...	0.50–0.13	140	1,200	3–5	600–900	**1600**	
	1	...	...	0.70–0.16	190	2,100	6–7	1000–1400	**2350**	
	2	...	...	1.00–0.18	140	3,450	10–12	1700–2200	**3200**	
	3	...	...	1.00–0.22	120	5,400	14–18	2500–3300	**3850**	
	4	...	...	1.20–0.22	120	6,750	18–20	3300–4000	**4300**	
Groke (Fig. 128)	0	...	...	1.40–0.11	45	1,650	4–6	800–1000	**1825**	Discount of 25 per cent. on catalogue prices.
	1	...	...	0.86–0.18	130	2,500	6–8	1500–1700	**2360**	
	2	...	...	1.40–0.18	85	3,100	8–10	2200–2900	**3125**	
	3	...	...	1.80–0.18	80	4,200	10–12	3000–4000	**3750**	
	4	...	...	2.00–0.21	65	6,100	12–14	4000–4600	**5000**	
Johnson (Figs 118, 126)	3	...	...	0.95–0.11	126	5,080	8	1500	**3800**	
	2	...	...	0.95–0.22	130	12,200	14	2000	**7500**	This machine has a roller.

GENERAL REMARKS ON THE MECHANICAL MOULDING OF BRICKS—CHOICE OF MACHINES—SCHEMES OF INSTALLATION.

When should machine manufacture be preferred to hand manufacture? The question is not always easy to answer. It is evident that the first condition is a considerable annual output, which we should estimate at two million bricks. In a factory of such importance every machine working by hand or animal power should be rejected—pug-mills, expression machines, etc. The work of these is as good as those driven by steam-power, but their small output makes their employment a costly one. They can only be recommended in small works for making hollow articles; they have also their advantages in new countries where animal-power is the only kind available.

But a large output is not the only condition in favour of mechanical manufacture. Factories doubtless exist which produce millions of bricks by hand, and such a quantity of productions can only find a market in a great centre of consumption; but in such a centre many hollow bricks and chimney-pipes are used, that is to say, many hollow articles which require machines. As soon as the manufacturer needs power for one part of his work, it is certainly advantageous to use it for the remainder. It is true that his capital sunk is increased, but, on the other hand, he is no longer at the mercy of the inclemencies of the weather, which cause serious losses, and he no longer needs that vast space which hand-work requires.

In case the brick-maker is also tile-maker, there can be no doubt machinery is necessary.

Once this question answered, another presents itself: what machine is to be chosen? That is more difficult to answer. In a general way it can be said that all machines are good; but to get good results we must choose the one which suits the clay to be worked. Many disappointments have occurred through a mistaken choice of machines and the use of one unsuited to the clay under treatment. We must insist, then,

on this important point: *It is not every machine which is suited for treating a given clay.* Anyone who knows the diversity of clays will understand that only a practical examination of a clay will teach us the most suitable way to treat it. Nevertheless, taking the principal varieties of clay, we shall be able to give a few general hints as to the tools to be used in the manufacture of bricks by expression machines.

Vegetable Moulds (*tableland clay, lehm, or loess*).—Weathering is always to be recommended but is not indispensable. Clays which have not weathered need to be passed between cylinders to crush the lumps and make sure of a better damping. The latter will be done in the mass, or more quickly with a moistening machine. Then the clay will be pugged and moulded by a machine with propelling cylinders; we do not advise screw machines. We pass over clays containing stones; it is better not to use them. Nevertheless, if the stones do not inconvenience the firing, such a clay can be used after being passed between crushing cylinders and reduced to powder. In the contrary case, and if no other clay can be used, stone-removing machines must be employed. To summarise, the following processes will be carried out, according to the circumstances of the case:—

Clays with stones.		*Clays without stones.*	
Crushing or stone-removing by cylinders.		Weathering or Rolling.	
Damping	Damping.	Rolling	or Damping.
Pugging	Pugging.	Damping	Pugging.
Moulding	Moulding.	Pugging	Moulding.
		Moulding.	

Potter's Clays or Clay Marls.—The same remarks as to weathering apply. Treated in the fresh state, these clays are cut into pieces in a mixing mill, then dipped into ditches with or without the addition of antiplastics. The mixture is pugged, and then moulded by means of cylinder or screw machines. When more or less dry clays are used, the mixing is replaced by crushing with antiplastics or other clays. Sometimes the sand used as an antiplastic contains hard lumps which have to be crushed; then it is passed with the clay between cylinders

which effect a first blending. Then the treatment will consist of the following processes, according to the state of the substances employed:—

Green clays.	*Dry clays.*
Mixing.	Crushing.
Soaking.	Rolling with antiplastics.
Pugging and shortening.	Soaking.
Moulding.	Pugging.
	Moulding.

Rich Clays.—These are not cut up, they are passed between cylinders to crush the lumps, then soaked, alone or with antiplastics; the mixture is then pugged, and afterwards moulded by cylinder or screw machines. Let us now examine in a more detailed manner each of these operations.

Crushing and *stone-removing* require no special remarks; it will be sufficient to refer to what we have previously said on the subject. As to *rolling with cylinders*, it must not be forgotten that the action of the cylinders is more rapid when their diameter is greater. If the clays are not held by the smooth cylinders, recourse must be had to those with points or flutings.

Moistening and *soaking* should receive special attention from the manufacturer. In brick-making we have not to bear in mind, as we must in tile-manufacture, certain considerations in favour of working on soft clay in preference to firm or hard clay. We must choose a convenient degree of dampness, which gives products neither too soft nor too firm. Pastes which are too soft undoubtedly require less power, but the products are not easily handled without loss of shape; hard pastes have the advantage of giving bricks firm enough to bear a pile of five or six without loss of shape; but considerable force is expended, machines are quickly worn out, and there is a risk of producing exfoliated pieces; moreover, the output is small. The best thing is to choose the happy mean between these two methods, that is to say, to mould with a semi-firm paste, the products of which can be placed in stacks, three or four bricks high, without loss of shape. In this way the production will reach its maximum with a moderate use of motive force.

The more plastic a clay is, the better can it be expressed in a firm state, subject to the remarks above.

Pugging is always effected by blade or screw machines: this is the best way to get a homogeneous paste, and in this respect cylinder-pugging is not to be compared with it. Horizontal pug-mills are preferable to vertical ones for effecting difficult mixtures with substances of different density.

Moulding is done by machines with cylindrical or screw propellers; the latter are not recommended for the treatment of thin clays, which cannot bear the same manipulation as rich clays. For the latter both kinds are suitable, but some manufacturers are inclined to prefer cylinder to screw machines. In any case, when using the latter, it is advisable to take machines in which the screws have a high pitch but not too great a length.

When the same machine is to make, besides bricks, chimney-tops and pipes, we may use a cylinder machine of the type of the Joly machine (Fig. 101) on account of its arrangement, which allows of its producing these articles (Fig. 575).

Another important question to be decided is, whether it is better to put up one single machine capable of producing the whole daily number of bricks required (machines can be found which produce up to 10,000 bricks an hour), or to divide the production between several machines of moderate power. In our opinion the latter course is better in most cases, for it must not be forgotten that a powerful machine is not suitable for the manufacture of hollow bricks, and it is easier to regulate production with several machines than with a single one.

It may be useful to point out the precautions which should be taken to ensure the regular working of machines, to whatever system they may belong.

When empty, a machine should be easily turned by hand; if there is a difficulty, the cause should be ascertained (tightness of bearings, want of oil, etc.). The distributing or propelling cylinders should be two to three mm. (about $\frac{1}{10}$th in.) apart, and even less if the product to be expressed is of small section.

The scrapers are placed near the cylinders, but not touching them. Whenever the thickness of the clay sticking to the cylinders becomes too great, the scrapers should be brought nearer. This is very important, because the output diminishes if the cylinders are not properly cleaned. The dies should be kept very clean, and care should be taken not to drop oil on the leather of those with water-face. Before fixing them to the machine, they should be dipped in water for a few minutes. It is better not to leave them on the machine during a long cessation of work; they should then be cleaned.

The cutting-table should be placed quite horizontal in front of the die; the skin-covered rollers should be moistened, and should be on the level of the lower edge of the die. The wires are placed at the proper distances starting from the pallet and tightly stretched. In order not to strain them uselessly, they may be loosened during stoppage of work. The rollers should always be kept clean, and those made of plaster should be renewed as soon as they are perceptibly worn.

When starting, it is recommended, especially in the case of thin clays, that the interior of the compression chamber should be filled by means of the hopper with soft clay; the first products which issue are rejected; this precaution facilitates the passing of the clay under treatment. It will also be advisable, if it is observed that the production diminishes, to take advantage of a stop to take out the closely compressed clay fitting the chamber, and to substitute some soft clay for it.

In screw machines fitted with cylinders, the production of these latter should be equal to that of the screws, otherwise there will be an obstruction which will force the clay under the scrapers; this defect can be remedied by bringing the cylinders closer together.

Generally speaking, whenever the output of a machine diminishes, we must seek the cause, which is often found to be an error in damping, too firm clay, cylinders too far apart, scrapers too far away, die out of order, screws worn, etc., all of which causes are easily remedied.

The maintenance of the machines belongs to the domain of

the ordinary routine of any mechanical factory; we will not therefore lay stress upon it.

Types of Installations.—The installation of a brick factory depends too much upon local circumstances for us to give precise details on the subject; we must be content with a few general hints. A very common arrangement consists in the construction of a building of two or three storeys, having on the ground-floor the kiln or kilns, and on the other floors drying-rooms which receive heat from the kilns. At the end of these kilns are placed the machines. Communication between the machines and the drying-rooms is made either by brick-elevators (Fig. 187) or by lifts to carry up the waggons and barrows, or by inclined planes.

When space allows, and work is suspended during the winter, open-air drying-grounds are used instead of drying-rooms in storeys. We will speak of them in the chapter on drying.

Economy of labour should be our guide in the arrangement of the machines. As far as possible the clay should pass automatically from the pit to the machines, and from them to the drying-rooms, the workmen's hands being used as little as possible.

Installation comprising Rolling, Damping, Pugging, and Moulding Machines.—This is for a thin clay easily damped like the vegetable moulds (lehm and loess); a compact factory might be arranged as follows.

The dividing cylinders are over the moistening machine; they receive the clay direct from the pit and pass it, well divided, to the moistening machine. When it issues from the latter, the clay falls into a vertical pug-mill, and the blended paste is then received into a cylinder expulsion machine, which transforms it into bricks (Fig. 153).

Dividing cylinders and the moistening machine are not indispensable, especially for clays which have undergone weathering, but they facilitate and hasten the treatment. In fact, the clay is always extracted in more or less large blocks; in order to get a regular moistening these blocks must be split up with the pick or shovel in a slow and irregular manner. The clay

must be arranged in layers for damping, then damped with a

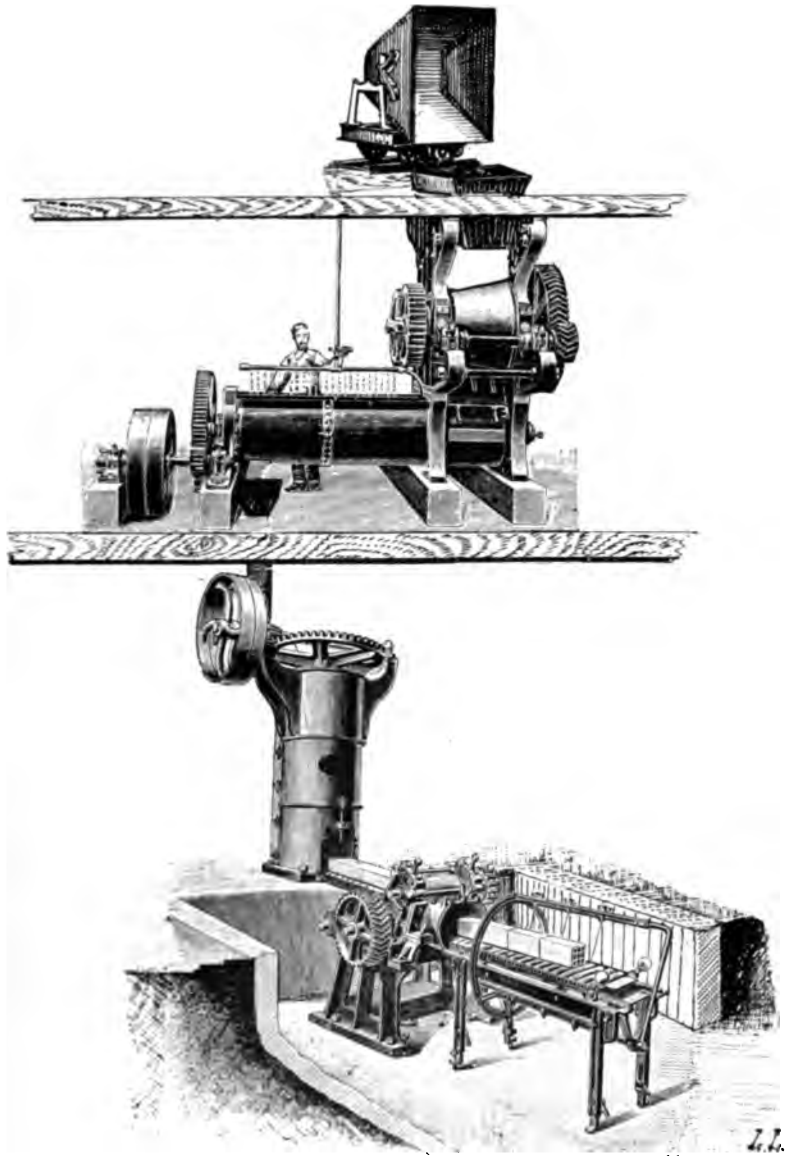


Fig. 153.—Type of Installation comprising Separating Cylinders, Damping Machine, Pug-mill, and Cylinder Expression Machine.

watering-can and left for *at least twenty-four hours.* Then it is cut up and thrown into the machine. But it often happens,

when there is a large quantity of clay to be moistened, that a sufficient volume cannot be prepared in advance, or that the distance between the heap of clay and the pug-mill is too large for a single stroke of the shovel; a second workman is then required to bring the clay nearer, and the daily cost is increased.

The arrangement shown gives great economy of labour, and whenever the clay is suited for this kind of treatment we should not hesitate to adopt it. Some makers say that their machines treat the clay without previous blending. This is true, but the considerable loss caused by the clay being insufficiently worked up soon makes up, and more, for the cost of a pug-mill.

Estimate of an installation of this kind, producing from 25,000 to 30,000 bricks per day of 10 hours.

	Francs.
2 moistening machines, each producing about 1500 to 2000 bricks per hour, at 2500 francs . . . . =	5,000
2 pug-mills, each producing about 1500 to 2000 bricks per hour, at 1800 francs =	3,600
2 cylinder expression machines, able to make pottery, producing about 1500 bricks per hour, at 2100 francs . . . . =	4,200
Belting, transmission, gearing	1,200
Motive power necessary: 15 to 20 horse-power for damping and cylinder machines, 8 to 10 for pug-mills, 6 to 8 for moulding machines—in all, 40 horse-power, costing for engine and boiler and erection about . .	20,000
Installation of a lift, if the drying-rooms are in storeys, or waggons and tramway if the drying is in the open air, about	5,000
Sundries	1,000
	40,000

The building is estimated at . . . .
for generally it serves to shelter the kilns, and its price is added to theirs.

An installation of this kind allows of an annual output of 6 to 10 millions, according as work is carried on for 7 or 8 months or for the whole year. It requires as staff: 1 engine-driver; 2 men to empty the waggons as they arrive automatically, and to put the clay in the rolling machines; 2 men for the damping machines; 2 men for cutting; 3 men to carry bricks and place them in the drying-sheds—in all, 10 men.

Net cost of 1000 bricks: $0.22 \times 0.11 \times 0.065$.

	Francs.
Interest at 4 per cent. on 40,000 fr. = 1600 fr. } 5600 fr. Depreciation ,, 10 ,, ,, = 4000 ,, }	
Per 1000, taking minimum output: $\frac{5600}{6000} = 0.93$ fr.	0.93
10 men at 5 fr. per day = 50 fr., or, per 1000, $\frac{50}{30} = 1.67$ fr.	1.67
Carry forward	2.60

		Francs.
Brought forward		2.60
Coal, 1 kilo per horse-power-hour = 400 kilos at 25 fr. the ton . . . . . 10 fr.	15 fr., or, per 1000, $\frac{15}{30}$ =	0.50
Oil, repairs, etc., per day . . . . . 5 fr.		
	Total .	3.10
To this we must add the cost of extraction of the clay, which varies (p. 32) from 1 fr. 30 to 2 fr. 20, according to the gradient (2 cubic metres per 1000 bricks)—the average is		1.75
	Total cost .	4.85

We must add the cost of pressing for high-class bricks; this is estimated at from 2 to 3 fr. per 1000.

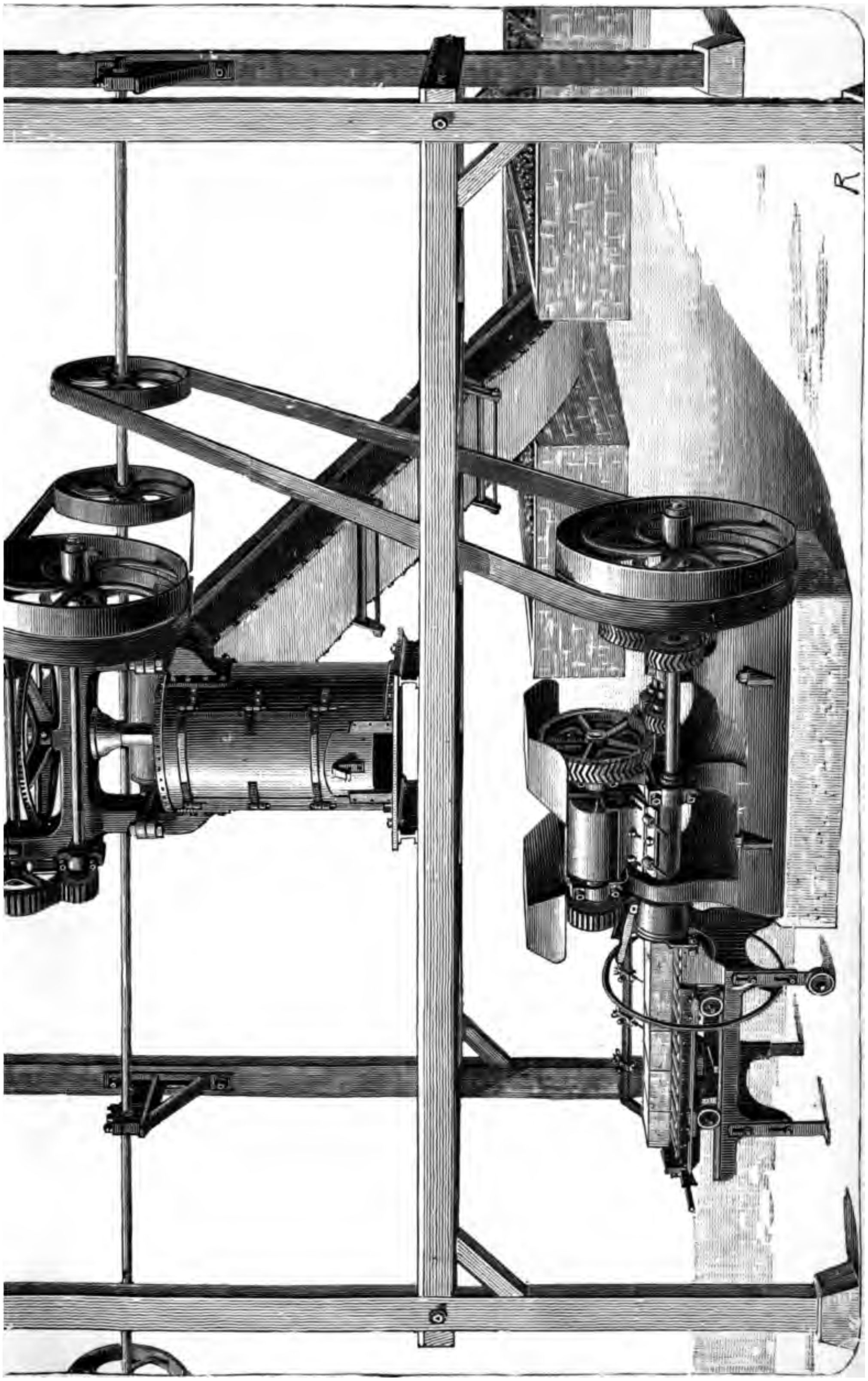
Installation with Soaking Troughs.—When the clays are rich and require soaking in troughs, the following arrangement may be adopted (Fig. 154). An endless band brings to the pug-mill the clay which has been soaked in the troughs, and after pugging the clay falls into a machine which transforms it into bricks.

We suppose in this installation that the clays do not need to be separated. Rich clays should generally be mixed: Fig. 155 shows an installation in which the mixing mill is placed above the soaking troughs. These troughs are provided with doors in one side, and near these doors is placed a pug-mill. The workman cuts the clay out of the troughs vertically and throws it into the pug-mill. Thence it goes to the moulding machine.

Estimate of an installation of this kind, producing from 25,000 to 30,000 bricks per day of 10 hours.

	Francs.
2 mixing mills, at 1100 francs . =	2,200
2 pug-mills, at 1800 francs . =	3,600
2 cylinder machines, at 1600 francs . =	3,200
Belting, gearing, etc.	800
Motive force: 4 horse-power for the mixing mills, 8 to 10 for the pug-mills, 6 to 8 for the moulding machines—in all, 25 horse-power, costing for engine, boiler, and erection, about	15,000
Lift or tramway with waggons, soaking troughs, and sundries	6,200
	31,000
Building	

The daily output requires a staff of 1 engine-driver, 2 men for the mixing mills, 2 men to spread the clay in the troughs, 2 men to fill the pug-mills, 2 cutters, and 3 men to take the bricks to the drying-rooms—altogether, 12 men.



Net cost of 1000 *bricks*: $0.22 \times 0.11 \times 0.065$.

				Francs.
Interest at 4 per cent. on 31,000 fr. = 1240	4340 fr.			
Depreciation ,, 10 ,, ,, = 3100				
Per 1000: $= \frac{4340}{6000} = 0.723$				0.723
12 men at 5 fr. a day = 60 fr., or, per 1000, $= \frac{60}{30}$			=	2.000
Coal, 1.25 kilos per horse-power-hour = 310 kilos at 25 fr. the ton	= 7.25 fr.	12 fr., or, per 1000, $\frac{12}{30}$	=	0.400
Oil and maintenance, etc.	4.25 ,,			
				3.123
Extraction of the clay, per 1000 bricks				1.877
		Total cost		5.000

Installation for Manufacture with Powdered Clay.—We shall give as a last example of installations, one for manufacture with dry clay. The dry state is obtained by natural means, or more frequently by warming in a stove or in the kilns. The clay, having been crushed by a mill with perforated pan, falls into a receptable below, whence a lift takes it to a sifting cylinder. The powder is received into a damping machine, and the tailings are returned to the crushing mill. The clay having been suitably moistened is once more mixed in a mill and finally falls into a receptacle, whence it reaches the press through a conduit. These presses (Fig. 157) are placed near the kiln, for the bricks manufactured by them are hard enough to be at once fired.

The estimate of such an installation is as follows:—

		Francs.
2 crushing mills, at 5350 francs	=	10,700
2 sieves, at 675 francs	=	1,350
2 damping machines, at 835 francs	=	1,670
2 mixing mills, at 3000 francs	=	6,000
5 moulding machines, at 5300 francs	=	26,500
Belting, gearing, lifts, etc.		3,000
Motive force: 10 horse-power for the crushing mills, 6 for the sieves and damping machines, 6 for the mixing mills, 20 for the moulding machines—in all, 42 horse-power, costing for engine, boilers, and erection, about		20,000
Sundries		1.780
Total for machines		71,000
Building, about		9,000
Total		80,000

The staff comprises: 1 engine-driver, 2 men to put the clay into the crushing mills, 5 men for the machines—altogether, 8 men.

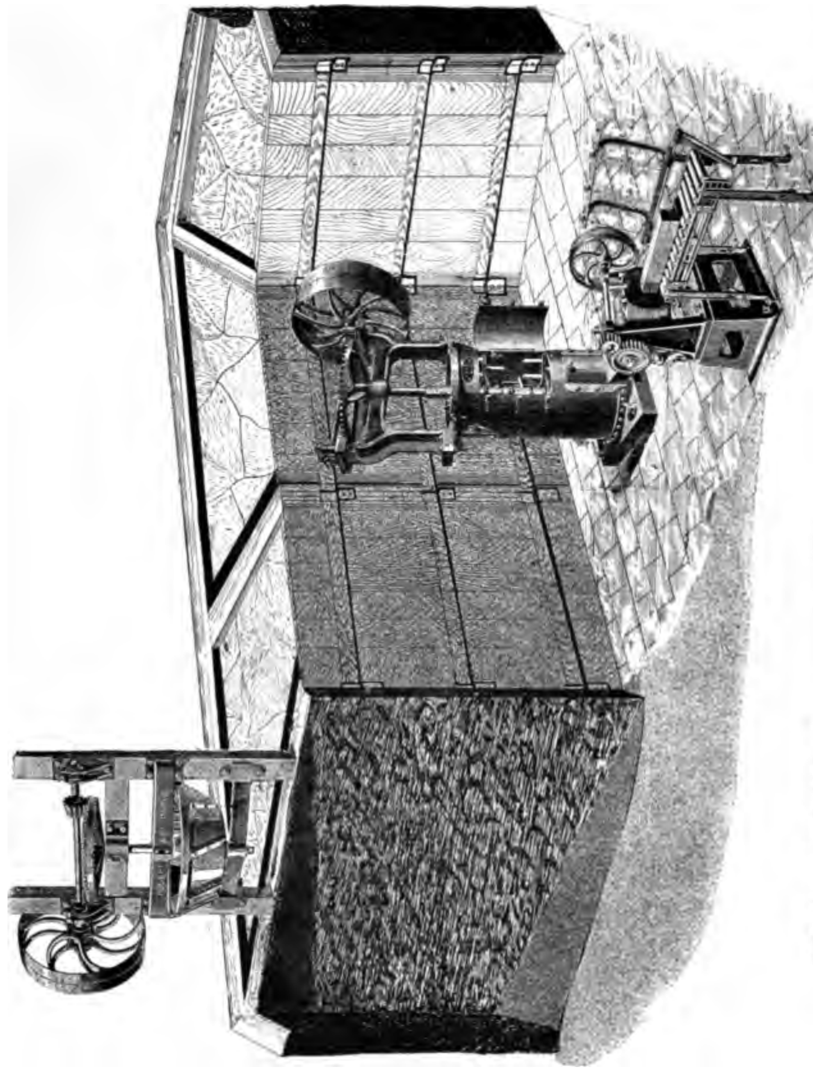


Fig. 155.—Type of Installation comprising Mixing Mill, Pug-mill, and Cylinder Machine.

Net cost per 1000 *bricks*: 0.22 × 0.11 × 0.065.

	Francs.
Interest at 4 per cent. on 80,000 fr. = 3200 fr. ⎫ 11,200 fr. Depreciation ,, 10 ,, ,, = 8000 ,, ⎭	
Per 1000: $\frac{11,800}{6,000}$ = 1.966 fr.	1.966
8 men at 5 fr. per day = 40 fr. per 1000 ÷ $\frac{40}{30}$ = 1.334	1.334
Coal, 1 kilo per horse-power-hour = 400 kilos at 25 fr. . . . . 10 fr. ⎫ 18 fr. per 1000 = $\frac{18}{30}$ = Oil, maintenance, etc. . . . . 8 ,, ⎭	0.600
To this sum we must add the cost of extraction of the clay, and that of drying it, which may be estimated at 1 fr. per 1000 bricks:	
Extraction of clay	1.750
Drying of clay	1.000
Total cost .	6.650

This is higher than the preceding estimates; but it must be observed that, in an installation of this kind, drying-rooms, transport of bricks to drying-rooms, and pressing are not required.

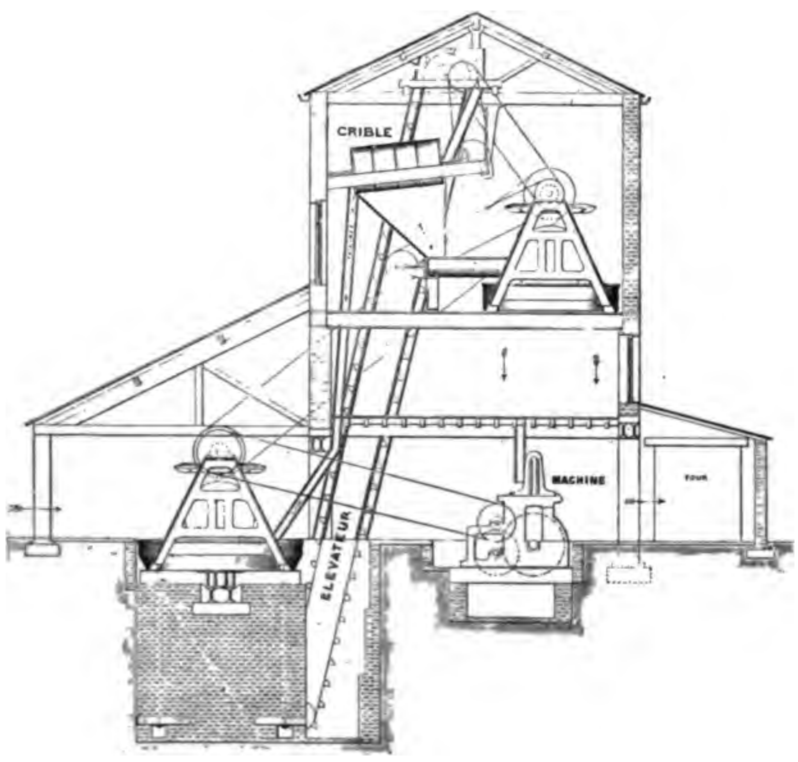


Fig. 156. Type of Installation for Manufacture with Dry Clay.

STAMPING.

The object of this process is to give to the bricks when they come from the ordinary machines the sharp edges and regular faces lost by them under the manipulations to which they have been subjected when in a soft state, however much care

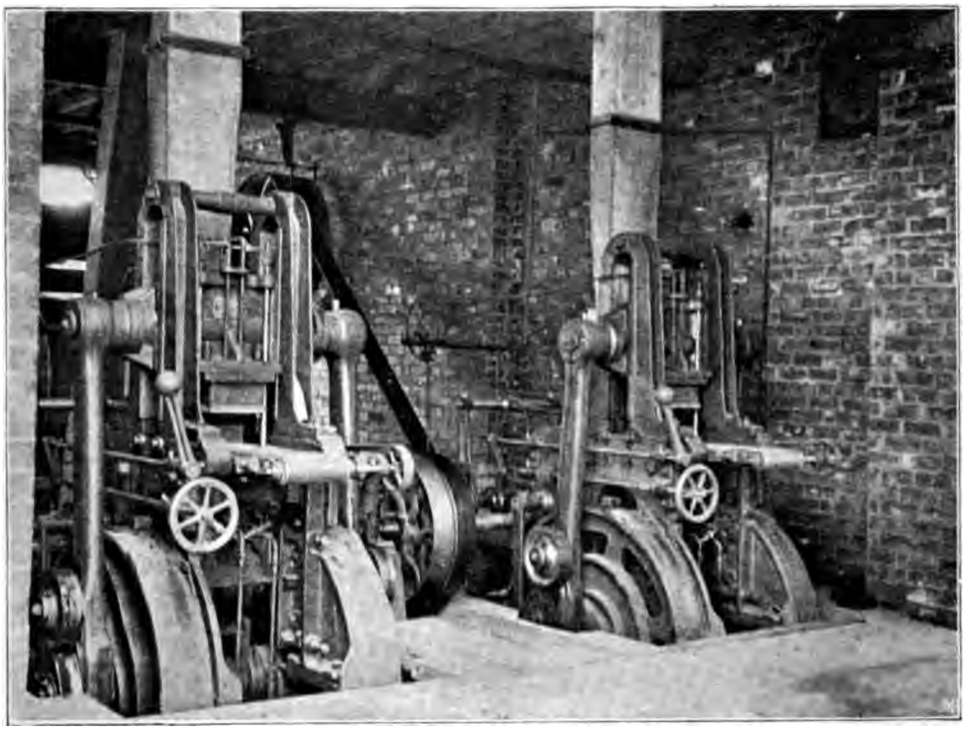


Fig. 157.—Installation of Whittaker Machines.

may have been given to their treatment. In other cases stamping is intended to further compress together the molecules of the clay; this is the case when bricks made by hand or by the lever press (Fig. 89) are so treated.

Stamping takes place a certain time after manufacture,—twelve, twenty-four, and forty-eight hours,—in order that the bricks may have become firm, and may undergo no further change of shape after the operation. We must, however,

avoid any drying of the surface, for a too dry clay would not take the shape of the mould. The hand-stamping formerly practised exists no longer since the introduction of stamping machines or "rebatteuses." We know that the invention of these ingenious machines is due to Brethon, a Tours manufacturer. All the other machines are only copies of that press. It is composed (Fig. 158) of two cast-iron standards bolted to a solid wooden platform and joined at the top by a cast-iron table which carries the mould. These standards carry a cast-iron

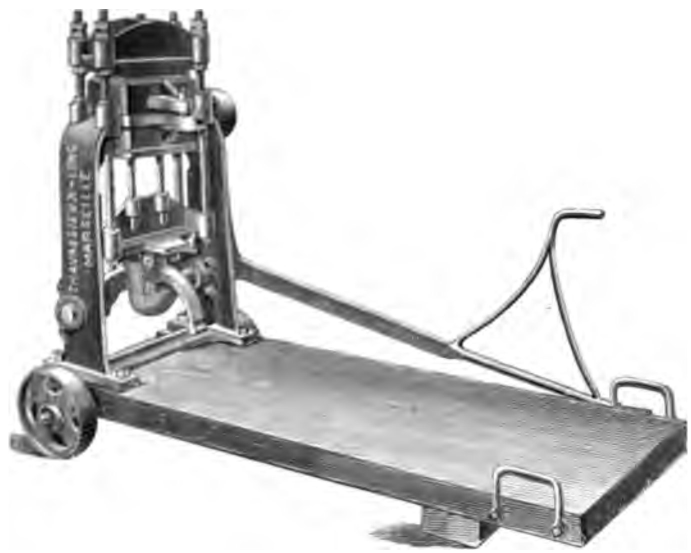


Fig. 158. Brethon Stamping Press (Chavassieux).

piece called "poitrine," to which the cap of the machine is fixed by two rods. The "poitrine" also has a central opening fitted with little steel friction rollers; those at the top are movable about an axis, those below are fixed. Between these slides passes a special piece quadrant-shaped and fixed to a curved shaft which turns on two bearings in the two uprights. At the end of this shaft is fastened a lever with a counterpoise.

The mould is formed of a cast-iron piece (Fig. 160) placed on the table and held by bolts. The inside is often lined with copper; the bottom (Fig. 160) is movable. It rests on the

table, and the lower rod with which it is furnished passes through an opening in the table and rests against the "poitrine"; it is this rod which removes the brick from the mould.

How does the machine work?

When the lever is raised (Fig. 161) the plate at the bottom just touches the upper part of the mould; the distance between the cap, which is furnished with an adjusted plate just sliding in the mould, and the upper part of the mould is large enough for a brick to be introduced. This distance is regulated according to the thickness of the brick, by raising or lowering the cap, which is fixed by four bolts to threaded rods.

When the brick is placed on the movable bottom, the

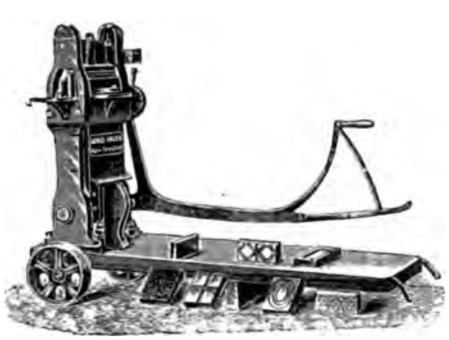


Fig. 159.—Stamping Press (Jäger).

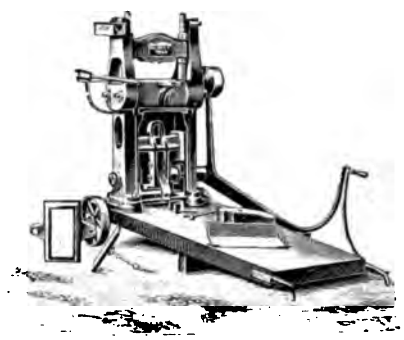


Fig. 160.—Stamping Press (Laeis et Cie.).

lever is sharply brought down with some violence (Fig. 162). The shaft to which it is fixed turns through a certain angle, and the quadrant-shaped piece, resting on the lower roller of the "poitrine," brings the latter down and with it the upper cap.

The bottom of the mould, the rod of which is no longer supported by the "poitrine," drops, but soon meets the cast-iron table and stops. The brick is then compressed between this bottom and the upper cap, and thus takes perfectly the shape of the mould, at the same time acting as a spring and throwing the lever forward again. This movement is assisted by the counterpoise, and it is sufficient to seize the lever to bring it back into its first position. But in rising, the shaft has

brought back the quadrant-shaped piece which it bears, and by this motion has raised the "poitrine" again, consequently also the cap and the rod of the movable bottom of the mould: the brick reappears in its former position, but stamped or "*repressée*," as it is called.

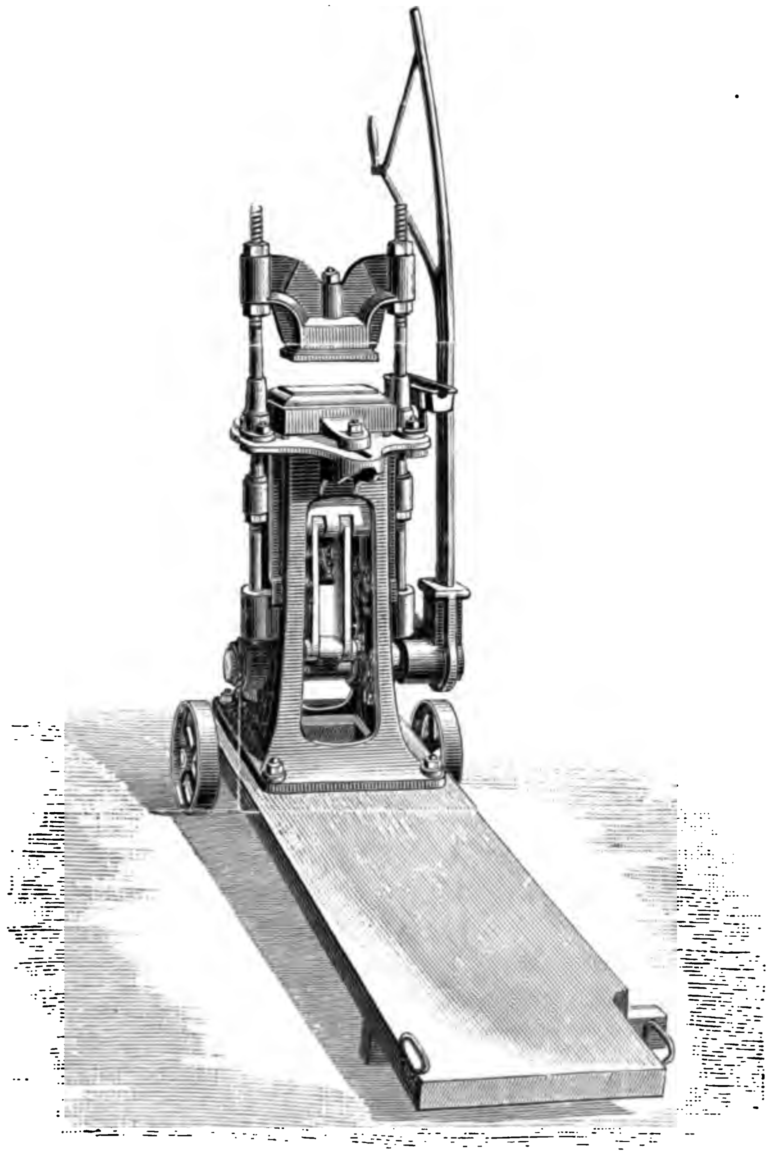


Fig. 161.—Stamping Press (Boulet).

The ascending movement of the "poitrine" is facilitated by the revolution of the friction rollers on which the curved piece acts. This revolution, to be as smooth as possible, requires lubrication. Moreover, the vertical rods, which run in guides and sockets placed on the cast-iron table, also require lubrication. These rods bear all the strain of the sliding motion, and are soon worn; this gives play to the machine. To remedy this wearing away, the cap is sometimes furnished with two other rods which slide in sockets (Fig. 158), or sometimes the ends of the cap are guided by fixed slide-bars, as in Figs. 159 and 160.

Fig. 162.—Stamping Press (Lacroix).

Fig. 163.—Stamping Press (Whitehead).

In these figures the "poitrine" is hidden by a sheet-iron plate to protect the frictional parts from dust, and the curved piece is surrounded by a sheath to avoid accidents.

The action of the machine is very simple, as can be seen from Fig. 162, which shows the workman bringing the lever forward and the boy preparing to put in another brick.

This machine and the following ones (Figs. 158–165) are based on the same principle as the foregoing. They only differ as to details, and especially in the way in which the lever moves the cap, and so exercises the compression. In the Lacroix and

Boulet machines, the framework is in one single piece instead of consisting of two uprights; this makes the machine more rigid.

In the Joly machine (Fig. 165) the movement is effected by means of a cam working on friction rollers; the whole piece bearing the rollers is guided below by a shaft sliding in a ring fixed to the base of the machine.

This press produces considerable effect, but it is less easily handled than the preceding ones.

The same maker has thought of moving the mould upwards by a system of cranks (Fig. 164). The cap being fixed, the working of this machine causes less violent shocks than in the

Fig. 164.—Stamping Press with Cranks (Joly).

Fig. 165.—Stamping Press (Joly).

previous ones; it can therefore be worked in any storey of the drying-rooms.

Fig. 163 represents an English press in which the parts are made extremely simple; the sketch sufficiently explains the machine.

The machine represented in Fig. 166 is typical of the German kind of press; its working is less simple and less rapid than that of the French kind, and nearly all German makers manufacture the latter (see Figs. 159 and 160).

It is easy with stamping presses to stamp the faces of the bricks in depression or relief; it is sufficient to provide the plates

of the cap and bottom with the design in relief if we wish to have it depressed, or in depression if we want it in relief.

Nevertheless, if we want clear-cut reliefs, it will be necessary to maintain the pressure longer than a stroke of the lever can effect. This result is obtained by using the Whitehead press (Fig. 167).

The operation is performed by means of an endless screw driven by a flywheel and handle.

Steam Stamping Presses. — The Jäger press (Fig. 168) is

Fig. 166.—Stamping Press, German Type (Jacobi).

Fig. 167.—Special Press (Whitehead).

composed of a piston with up and down motion which compresses the brick in the mould.

This motion is communicated to the piston by a crank and a system of bent shafts and cog-wheels as shown in Fig. 168.

Like those worked by hand, this press can also stamp any kind of ceramic product; it will be sufficient to change the moulds and substitute others suited to the shape and nature of the articles to be stamped. Screw and friction-plate presses as used for the manufacture of tiles can also be used for bricks. Fig. 169 shows a press of this kind fitted with a brick-mould.

Steam stamping presses are very little used because it is easy

to remove hand-presses when the circumstances of manufacture require it, and because the latter have as large an output as the former.

General Remarks as to the Stamping of Bricks.—It is an excellent method for giving bricks finish and a good appearance, indispensable qualities for those intended for façades, as they must have clean-cut edges and perfectly smooth faces.

The process is of no use for ordinary bricks, although many manufacturers subject them to it.

Fig. 168. -Universal Stamping Press (Jäger).

In choosing a machine, lightness is desirable, but rigidity must not be neglected. The double guiding of the cap and the easy lubrication of the frictional parts must be taken into consideration as well as the distance apart of the rods; this should be great enough for bricks of at least 0.30 metres (1 foot) to be stamped.

Cast-iron moulds give more clean-cut shape than those lined with bronze, and they do not wear out so quickly. But with the former the removal of the brick requires a lubrication of all the

faces of the mould, while with bronze-lined moulds it is sufficient to sprinkle the bricks with powdered dry clay, and this is done when they are in stacks or on the waggon when brought up to be stamped.

Notwithstanding the necessary lubrication, which increases the cost of stamping, owing to the oil used (generally resin oil), and the decreased output (due to time lost in greasing), preference should be given to cast-iron moulds if we wish to have fine products. The same press can stamp several kinds of products;

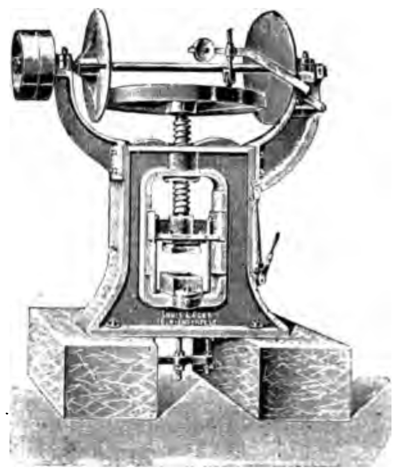


Fig. 169. - Friction Stamping Press (Jäger).

it is sufficient to change the mould, the bottom plates, and the cap.

We have already stated that bricks cannot be stamped immediately after they come from the expression machine; they must be left to gain firmness, until they are in a fit state, neither too hard nor too soft, to take the shape of the mould. When space allows, they are placed on edge on a level tiled floor, or on boards, whence they are afterwards removed to the press. This can easily be moved, and is placed in a convenient position. It is better to carry out the process on the ground-floor on account of the shocks produced by the action of the press.

If space is limited, the bricks are placed on shelves, and when they are ready to be stamped, the press is brought near them.

A workman takes the bricks from the shelves, and puts them in the mould.

PARTICULARS OF STAMPING PRESSES.

Name of Maker:	Chavassieux	Jäger.	Jacobi.	Joly.		Lacroix.	Laeis.	Whitehead.	
	Fig. 158	Fig. 159	Fig. 166	Fig. 165	Fig. 164	Fig. 162	Fig. 160	Fig. 163	Fig. 167
Weight of machine in kilos . . .	370	500	850	600	400	200	800	600	800
Price in francs with mould complete	550	. .	1000	500	570	350	850	350	625
Remarks . . .	Four guides.	Slide-bars.	Fly-wheel.	Lever and cam.	Lever and cranks.	Two guides.	Slide-bars.	. .	Special press without mould.

(2) DRYING.

The object of this is to take from the bricks coming from the machine or mould the uncombined water contained in them. The quantity of this is very variable: while it may be neglected in products made from dry clay, it reaches a maximum in bricks made from soft paste.

Drying is an important process; if it is complete, the firing will be easily and economically effected: if incomplete, the firing is rendered difficult and more costly.

In factories which continue work during the winter, drying should be carried out in closed drying-rooms warmed by direct heat, or, as is more generally the case, by transmitted heat from the kilns. In brickworks which are only open during the summer, the drying is done in the open air without shelter, or under sheds, or in storeyed drying-rooms.

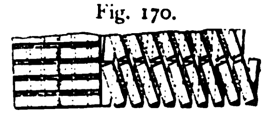
Open-air Drying.—*A.* WITHOUT SHELTER.—This is the most economical method; although excellent in hot countries, it often causes disappointment in northern countries, on account of the frequent rain; very often it has to be abandoned, and sheds are constructed.

The arrangements made are as follows:—

Near the place where the moulder works, a rectangular piece of ground of about a yard or a yard and a quarter in breadth, and of a length depending upon the space available, is raised in level. On each side of this bed two trenches (R R, Fig. 171) are dug in the following manner. A line is stretched in position, and along the line lumps of earth are taken up with a spade, and laid in a row by the cord. These lumps form the boundary of the raised plot; the trench is about a foot and a half wide. The space between the two parallel rows of clods of earth is filled with

HACK OF BRICKS.

Fig. 170.



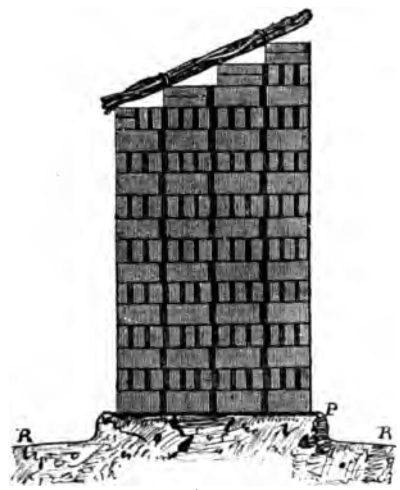


Fig. 171.

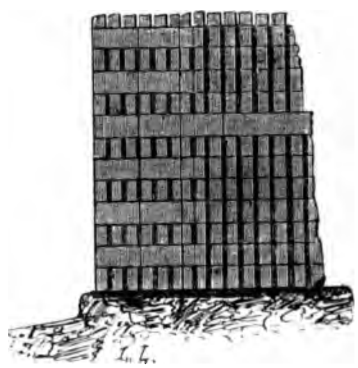


Fig. 172.

Fig. 170.—View from Above. Fig. 171.—End View.
Fig. 172.—Side View.

soil taken from the trenches, and if necessary from elsewhere; when well rammed down and dressed this forms the *foot of the hack* P.

On this foot the bricks are arranged in open-work *hacks*, the bricks being placed in an oblique direction which changes for each layer (Figs. 170, 172).

The first layer is sometimes composed of fired bricks, in order that the dampness of the earth may not soften the unbaked bricks supporting the whole hack; sometimes a layer of straw is put down. These precautions, which are useful at the beginning

and end of the season, are less so in the middle. Two layers at a time are stacked along the whole length, and thus four layers may be placed in position and then left to recover for a day or two so that they may harden and be able to support further layers. The vertical rows thus placed one over the other are called "*feuilles*"; the two middle "feuilles" are first erected, and as the air passes quickly between the bricks, drying is fairly rapid. For the sake of rigidity, not more than eight or ten rows should be placed on each "feuille," but the bricks at the foot are then dry enough for a new "feuille" to be begun on each side of them, so as to make altogether four "feuilles." When their height is sufficient to consolidate the middle "feuilles," more bricks are placed on them. Generally a height of 15 to 18 layers is attained, that is to say, about 5 to 7 feet. The top of the hack is so arranged that the straw matting [1] placed on it has the slope of a roof. Instead of matting, which soon wears out, tiles are often employed.

It will be easily understood that the total length of the hacks depends upon production, since only four layers at a time can be placed in position. For works producing 6000 to 7000 bricks a day, it will be seen that a length of 1500 to 1800 bricks will be required, that is to say that, counting 0.08 m. for the thickness of the brick and intervals, we must have one, or, better still, several hacks, with a total length of 120 to 140 metres. In the heat of summer this length is not necessary, but it is better to have it arranged in advance in order to avoid inconvenience in any case of bad weather. The great disadvantage of open hacks is that they are exposed to this. Therefore in a large number of factories they are sheltered by light wooden sheds like those represented in Figs. 173 and 174 and called "*hallettes*."

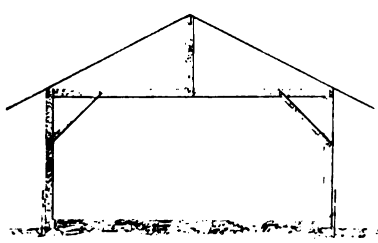
B. DRYING UNDER SHEDS. These sheds or "hallettes" are about 12 feet broad, the posts are 5 feet high, but the length is

[1] The matting consists of strong straw plaited together, and about two yards in length. It is attached above and below by two little switches arranged lengthways. Instead of straw matting, movable squares of wood of about thirty inches in height are sometimes used, and placed vertically against the bricks; over these, movable wooden roofs are placed which take the place of matting. In this case the hack is neither very high nor very broad, and the bricks are completely enclosed.

variable. To strengthen them against the wind, solid stakes are driven into the ground and nailed to the uprights, which, to avoid the dampness of the soil, rest upon baked bricks. In consequence of their lightness, these sheds are easily taken to pieces, and are moved as the work advances; the brick-maker should choose a convenient position, so that they may be used as long as possible. To obtain satisfactory drying the space between two sheds should not be less than 10 metres, so that air and light may have free access.

The same sheds do as well for hand-manufacture, either by the Flemish method or by lever presses, as for that by machinery. In the latter case, however, special precautions are advisable: we must avoid the action of the sun, which dries the bricks too

SHED OR "HALLETTE" FOR THE OPEN-AIR DRYING OF BRICKS.



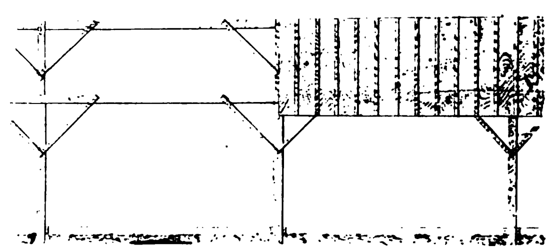


Fig. 173. -Transverse Section. Fig. 174. - Elevation with and without Planks.
(Scale of 1 centimetre to the metre.)

quickly and warps them. Certain clays cannot bear drying in the open air, but require closed drying-places in which even currents of air must be avoided. Under a shed such as we have just described, they begin by stacking two "feuilles" in the middle, and when the foot is quite dry, a third and a fourth are placed, one on each side, which dry in their turn; then another is placed, and so on. Only one row must be placed at a time, for any brick enclosed when fresh between other bricks, remains fresh and does not dry.

The thickness of the hack is as much as 14 to 16 "feuilles," the height at the centre is from 18 to 22 layers, that is to say, about 8 feet; but the other "feuilles" are not so high on account of the slope of the roofing. The bays are 4 yards long, that is to

say, about 50 bricks placed side by side with an interval of about a finger's thickness between them.

A shed 60 yards long (15 bays) can therefore shelter 230,000 bricks. But such a number is rarely allowed to accumulate, because for the requirements of manufacture room must be made from time to time, and the shed relieved of the dry bricks under its shelter.

In order to guard the bricks from the rain which might be driven by the wind under the shed, matting or brushwood is used and is laid against the foot of the "feuilles," when the weather is uncertain. But this precaution is only necessary when the hack is quite close to the side of the shed.

As deal of the usual trade dimensions is used, it is easy, knowing the price of the wood, to make an estimate of the cost of a shed (see p. 182).

C. Drying under a Collection of Sheds.—We have said that the preceding arrangement allows of the drying of

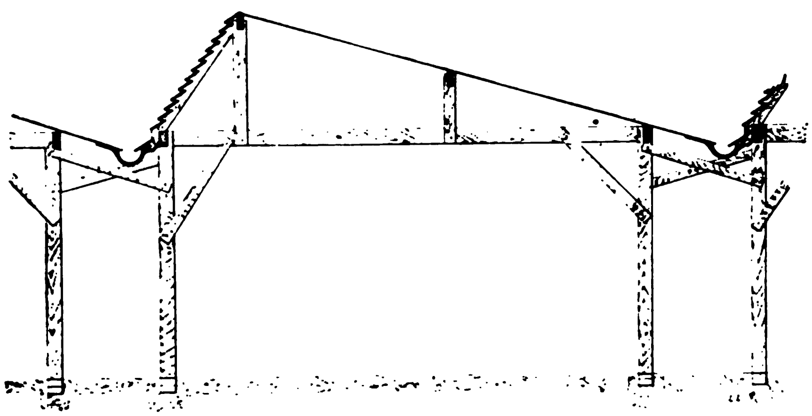


Fig. 175.– Section of several Combined "Hallettes." (Scale, 16 millimetres to the metre.)

machine-made bricks, but in this case, to avoid the too rapid action of the sun, it is advisable to place together a certain number of sheds, which thus form one single open surface (Fig. 175). One side of the covering is formed of Venetian shutters, which enable a draught to pass from the lower to the upper part of the shed. For this part of the covering a direction least

exposed to rain will be chosen. The other part is made of tiles or, more cheaply, of planks as in ordinary sheds; for the use of tiles almost triples the cost. A covering of tarred wood lasts twenty years or even longer, as we have observed in many cases. As economy is required in this class of construction, a simple zinc gutter 6 or 7 inches broad is used and fixed by hooks, and, to be ready for an always possible accident, the part between the uprights is reserved for a tramway or the passing of barrows. To avoid waste, the wood used should be of the usual trade dimensions, which, as we know, are measured in units of 33 centimetres (about 1 foot). For the estimate of such a shed, we refer the reader to p. 183.

Storeyed Drying-rooms.—These are used in factories containing continuous kilns. The kiln or kilns are placed in the centre of the building in such a way that the heat from them spreads to the different storeys by traps in the flooring. When necessary, vertical movable pipes are fixed to the holes in compartments which are cooling to conduct the heat to places where it is required. The bricks are arranged on the floor in hacks as previously described. Shelves are generally useless, except for bricks to be stamped, when the space at disposal is too limited.

The floors are strong enough to bear the weight of the bricks. Casements are placed in the walls, and are opened to produce draughts and hasten the drying of products which are not injured by air-currents. Such a drying-place can be constructed in various ways; above all things economy is desirable. Therefore any building which involves much masonry should not be considered; even iron is not economical enough, and we should recommend the erection of a simple one-storeyed or two-storeyed shed, according to the daily output. In order to avoid the use of pieces of large size which are always costly, we should substitute for them joists fastened together with bolts. Fig. 176 represents a drying-shed constructed in this way. The kiln has 20 compartments of 4 metres, and has a total length of 44 metres; the building over it is 48 metres long, and is divided into 12 bays of 4 metres. Its width is 20 metres, the

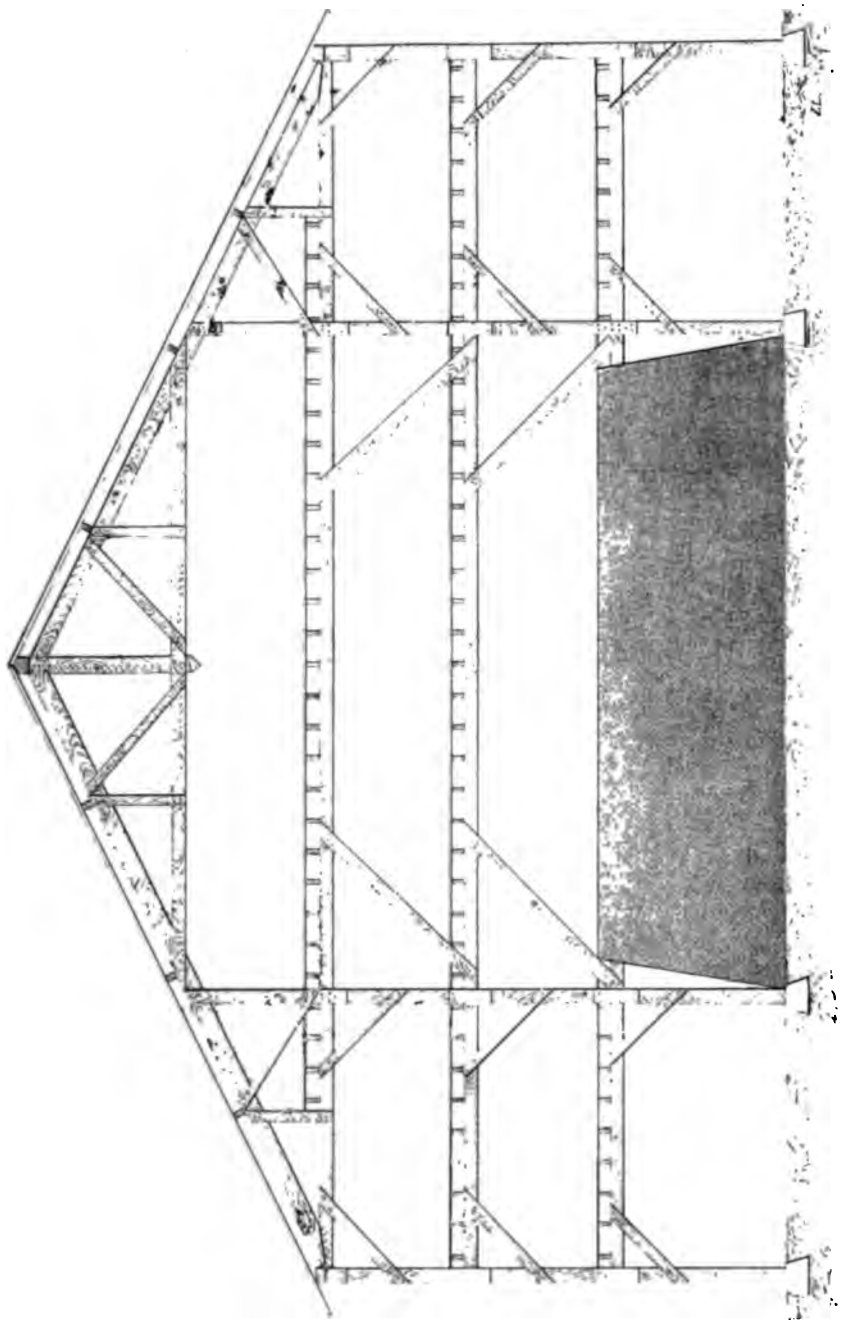


Fig. 176.—Building in Storeys for drying Bricks. (Scale of 8 millimetres to the metre.)

height of the storeys is 3 metres for the ground-floor and 2 for the others. Not including the surface of the kiln, and reserving the ground-floor for the management of the kiln and repressing of bricks, the surface of the drying-rooms will be: first floor $48 \times 20 - 44 \times 10 = 520$ square metres; second floor $48 \times 20 = 960$ square metres; third floor $48 \times 14 = 672$ square metres; making a total of 2152 square metres. From this surface we must take the passages necessary for circulation of vehicles and for ventilation. We will suppose that the same system of stacking is used as in open-air drying, which is the quickest and most economical. Allowing five "feuilles" thickness to the stack, that is about 1.15 metres, the empty space between each stack will be about one metre.

There will be then altogether: on the first floor $10 \div 2.15 =$ 4 stacks; on the second floor $20 \div 2.15 = 9$ stacks; and on the third floor $14 \div 2.15 = 7$ stacks; that is to say, a total of 20 stacks 48 metres in length, and each row in a stack will contain about 585 bricks. As two rows can be placed together, we see that by laying one row per day, $20 \times 2 = 40$ rows of 585 bricks each can be accommodated; this makes about 23,000 bricks. It is certain then that with a building of the dimensions stated above the daily production might be as much as 25,000 to 30,000, and this even under unfavourable circumstances; for it is rare, as we said on p. 172, that 3 or 4 layers cannot be stacked one over the other. But it must not be forgotten that in winter and in bad weather drying is a slow process.

The building shown in Fig. 177 is closed at the sides by a brick wall of 8 inches thick, provided with windows which allow of air-currents being produced. Some builders make the posts supporting the framework rest on the kiln (Fig. 231). This arrangement is not advisable, for, however strongly the kiln may be built, it undergoes expansion, which after a time would have a dangerous effect on the whole construction; besides, it is not worth while to be exposed to annoyances for such a slight economy.

In the flooring openings are made for the hot air to pass through; the communication between the storeys is effected by

staircases or inclined planes, but the bricks are raised by machinery.

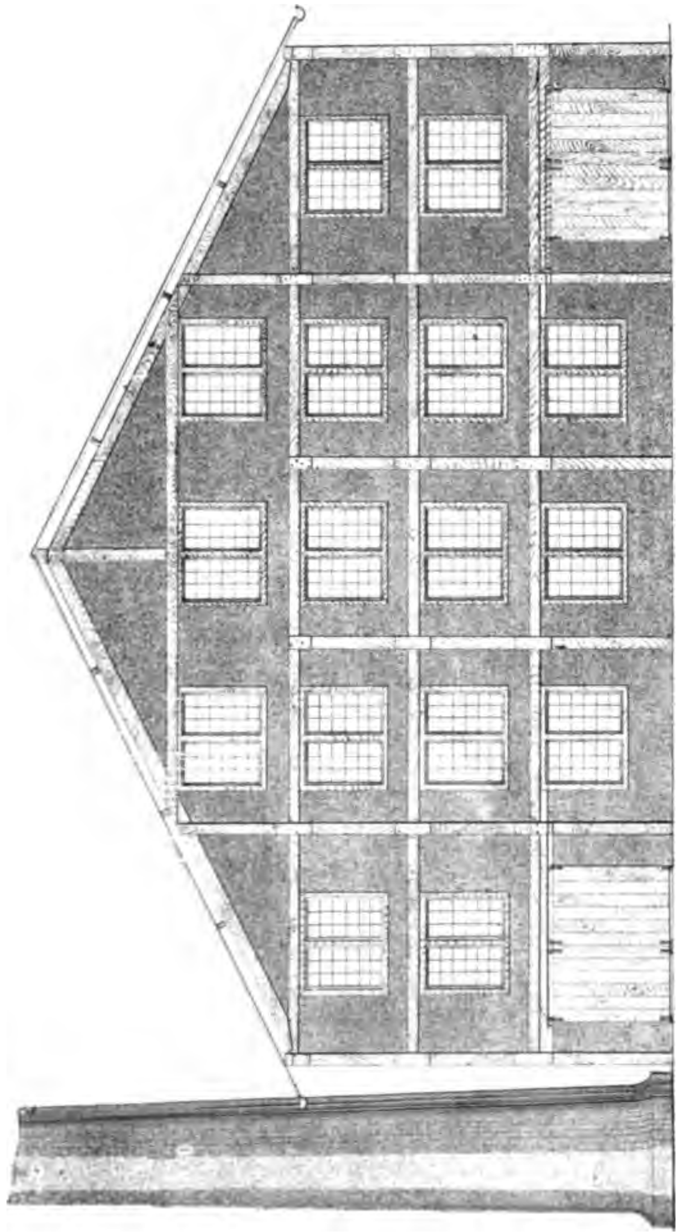


Fig. 177.—Drying-rooms in Storeys—Elevation of the Gable-end. (Scale of $6\frac{2}{3}$ millimetres to the metre.)

Storeyed drying-buildings contain open-air or closed drying-rooms according to the season; from the dimensions we have

given, it is evident that they occupy a large space, which increases with the daily production. In order to economise space, cost of installation, and labour, attempts have been made to carry out the drying in closed spaces by artificial means.

Closed Drying-rooms.—Numerous systems have been devised; attempts have been made to use the heat escaping from the kilns by bringing it into the rooms by special arrangements, and by using the draught of the chimney, and, later on, of a ventilator. But the handling of the bricks was a rather serious obstacle, besides the difficulty of bringing the hot air into the chambers, and the inconveniences caused to the working of the kiln.

Some have thought of using stoves warmed by a special furnace, and actively ventilated; and, to lessen the labour required, the products have been placed upon waggons and run into heated galleries, called tunnel drying-rooms. These are much used in the United States, where the manufacturing conditions are somewhat different from our own. The principle of these drying-tunnels is as follows:—

The products to be dried are introduced into a closed gallery, and automatically pushed forward, while at the same time a current of air is produced in the opposite direction; in this way the bricks meet more and more dry air as they advance, and finally arrive at the end of the gallery perfectly dry. In order to carry out this principle, the gallery contains a line of rails on which waggons with shelves, as in Fig. 186, run.

At the entrance of the gallery is a room with doors; through one door the products coming from the machines enter, the door is closed, and another leading into the tunnel is opened (Fig. 178). This tunnel is provided with a slow ventilation either by a ventilator or by draught from the factory chimney; but generally the latter is insufficient, and a ventilator is required. At the other end of the tunnel is an opening communicating with the outer air. In summer this air suffices for the drying, but in winter it is mixed with hot air given out by the cooling of baked products, or by any other economical method. The dry air from outside only acts upon objects containing very little moisture; it

has no bad effects upon them, and completes their desiccation. As the air advances through the tunnel it becomes more and more loaded with the moisture it receives from the bricks, and when it reaches the waggons last introduced, it is almost saturated: it therefore only takes from the fresh products the little moisture required to completely saturate it before being expelled. The quantity of air and its temperature must, for this reason, be carefully regulated as it enters.

When one waggon goes in, another comes out. Thus the action is continuous, and a few days are sufficient, at all times of the year, to effect drying. Besides, it will be seen from these

Fig. 178.—Tunnel Drying-room (Lacroix).

arrangements that the bricks, when once placed on the waggon, are not handled again until put in the kilns. We have just stated the advantages of this system of drying; we must now mention its inconveniences.

Of these, the most serious is, in our opinion, that it only applies to one kind of product. It will be understood, in fact, that in the kilns it is necessary to mix products in order to utilise space and also to satisfy requirements of consumers. But manufacture cannot exactly follow these different phases; with ordinary drying-rooms there is no inconvenience in this, since each kind of article has its own drying-place, whence it is taken

as required to the kiln. But with drying galleries, it is no longer the same; in fact, the products must follow one another in the order in which they are to be placed in the kiln, otherwise they will have to be handled again, and the benefit of economy in labour disappears, or else stock will have to be increased and a place reserved for loaded waggons which are not at once kilned. Another inconvenience, but one more easily remedied, consists in the behaviour of clays while drying. There are some which cannot bear the draught without splitting; others resist the current of air well, but crack under the influence of hot air. It

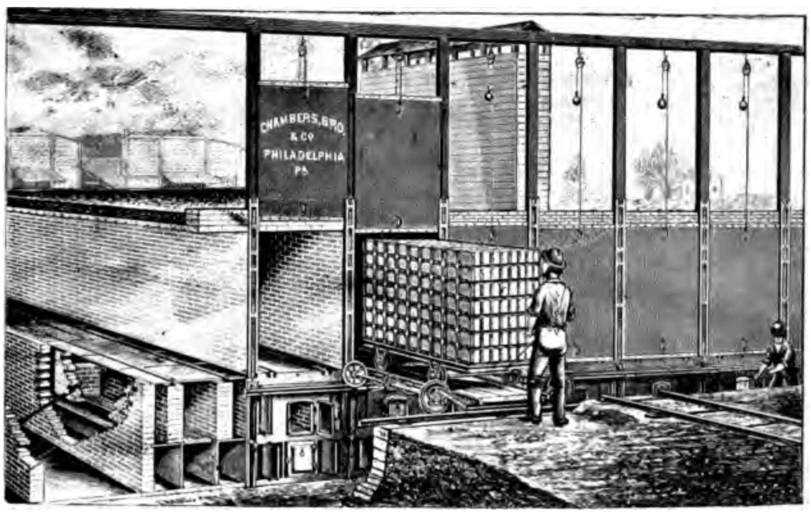


Fig. 179.—Closed Galleried Drying-rooms (Chambers).

is evident that these difficulties may be overcome by great precautions and a well-regulated current, but it must not be forgotten that, to attain results economically, the drying must be done in two days in order to reduce the stock of waggons. But all clays cannot bear such rapid desiccation, hence only experience can guide us.

To summarise, galleried drying-places are of great use in case of extensive manufacture of one single article with clay which bears rapid desiccation. That is why these drying-places are much used in the United States, where enormous quantities of the same article are made in one factory. Moreover, by the

arrangement adopted (Fig. 179), different products may be placed in the different galleries; but then the cost of installation is very high, and such an expense cannot be thought of for an output which does not exceed several millions, like the majority of French factories whose mean production is two to three millions and maximum about fifteen millions of one single article.

Estimate of the Cost of Different Drying-places. Comparison of these Prices.—The installation of drying-rooms for bricks should be as economical as possible; so we shall use, in the following estimates, only deal of the usual dimensions. It is evident that in places where the wood of the country will be cheaper than northern firwood, we must not hesitate to use it.

1. ESTIMATE OF A "HALLETTE" (Figs. 173 and 174):

			Joist.	
Cubic content of a truss.	2 Posts *A*, $0.22 \times 0.08 : 2$	of 1.66 m.	$= 2 \times 1.66 \times \frac{1}{2} = 1.66$ m.	4.408 m.
	1 King-post *A*,	of 1.00 m.	$= 1 \times 1.00 \times \frac{1}{2} = 0.50$ m.	
	1 Tie-beam *B*, $0.22 \times 0.08 : 4$	of 3.66 m.	$= 1 \times 3.66 \times \frac{1}{4} = 0.915$ m.	
	2 Supports *C*, $0.22 \times 0.08 : 6$	of 1.00 m.	$= 2 \times 1.00 \times \frac{1}{6} = 0.333$ m.	
	2 Piles *A*,	of 1.000	$= 2 \times 1.00 \times \frac{1}{2} = 1.000$ m.	

			Joists.	
Cubic content of an intertruss.	3 Purlins *B*,	of 4.00 m.	$= 3 \times 4.00 \times \frac{1}{4} = 3.00$ m.	19.95 m.
	6 Supports *C*,	of 1.00	$= 6 \times 1.00 \times \frac{1}{6} = 1.00$ m.	
	24 Planks *D*, $0.22 \times 0.08 : 5$	of 2.66 m.	$= 24 \times 2.66 \times \frac{1}{5} = 12.75$ m.	
	24 Cover-joints *E*, $0.22 \times 0.08 : 20$	of 2.66 m.	$= 24 \times 2.66 \times \frac{1}{20} = 2.20$ m.	

If we suppose that we have to cover about 2500 square metres, which represents 176 bays of 4 m. by 3.66 m., which we shall divide into 11 sheds of 16 bays, there will be: $17 \times 11 = 187$ trusses and 176 intertrusses. The total cubic contents will be:

$$\left.\begin{array}{l}187 \times 4.40 \\ 176 \times 19.95\end{array}\right\} = 4334 \times 0.22 \times 0.08 = 76.278 \text{ cubic metres.}$$

Recapitulation. Valuing the cubic metre at 80 francs, including preparation of the ground, various fittings, etc., the cost will be $76.278 \times 80 = 6102.24$ fr. 6102.24 fr.

Tarring of the outside extra: 3745 sq. metres at 0.40 francs .	1498.00
Sundries	99.76
Total .	7700.00 fr.

2. Estimate of one Bay of Combined "Hallettes" (Fig. 175).—The woods used are joists 0.22×0.08 and basting 0.15×0.06:

Cubic content of a truss.	2 Posts *A*, Joists of 2 m. $= 2 \times 2 \times \frac{1}{2} = 2.00$ m.	3.32 m.
	4 Ties *C*, „ 1 m. $= 4 \times 1 \times \frac{1}{6} = 0.66$ m.	
	2 *A*, „ 1 m. and 0.33 m. $= 1.33 \times \frac{1}{2} = 0.66$ m.	
	1 Tie-beam *F*, 0.15×0.06, Bastings of 4 m. $= 1 \times 4 = 4.00$ m.	$= 4.00$ m.

Cubic content of an intertruss.	6 Ties *B*, Joists of 1 m. and 2 of 0.66 m. $= 7.33 \times \frac{1}{6} = 1.22$ m.	13.22 m.
	12 Planks *D*, „ 4 m. $= 12 \times 4 \times \frac{1}{5} = 9.60$ m.	
	12 Cover-joints *E*, „ 5 m. $= 12 \times 4 \times \frac{1}{20} = 2.40$ m.	
	4 Purlins *F*, Bastings of 4 m. $= 4 \times 4 = 16.00$ m.	31.72 m.
	4 Plank-supports *F*, „ 1.33 m. $= 4 \times 1.33 = 5.32$ m.	
	13 Planks *G*, 0.15×0.06 : 5 of 4 m. $= 4 \times 13 \times \frac{1}{5} = 10.40$ m.	

Supposing a surface of 2640 metres to be covered, that is to say, about that of the storeyed building in Fig. 177, we should have a rectangle of 44.10 m. (9 divisions of 4.90 m.) by 60 metres (15 divisions of 4 metres), including $16 \times 9 = 144$ trusses and $15 \times 9 = 135$ intertrusses.

The total cubic content of such a drying-place would then be:

$$\left.\begin{array}{l} 144 \times 3.32 = 460.80 \\ 135 \times 13.22 = 1798.20 \end{array}\right\} = 2259 \times 0.22 \times 0.08 = 39.758 \text{ cubic metres,}$$

and

$$\left.\begin{array}{l} 144 \times 4.00 = 576.00 \\ 135 \times 31.72 = 4282.00 \end{array}\right\} = 4858 \times 0.15 \times 0.06 = 43.622 \text{ cubic metres.}$$

Total . 83.380

Recapitulation.—The cubic metre is valued at 80 francs, erection and all fittings included, that is:

83.380 c.m.	at 80 fr. =	6670.40 fr.
600 metres of gutter	at 2.50 fr. =	1500.00 fr.
Tarring of 3250 metres with Norwegian tar	at 0.40 fr. =	1300.00 fr.
Preparation of the ground, kennel-stones for running off the water, and sundries		529.60 fr.
	Total .	10,000.00 frs.

A drying-place of these dimensions does very well for a daily production of 25,000 to 30,000 bricks; it can evidently only be used during the summer. Being strongly built, it is sure to last at least thirty years, and may certainly last longer.

2A. COMBINED "HALLETTES" ROOFED WITH TILES.—The volume of wood required is as follows:

	Joists.
Cubic content of a truss.—The posts are doubled, the rest is unchanged	5.32 m.
	Basting.
No change for the basting	4.00 m.
	Joists.
Cubic content of an intertruss.—The planks and cover-joints disappear, there remains then	1.22 m.
To the basting, there must be added 5 rafters of 0.06 × 0.07 4 metres long; that is to say, 10 metres extra	41.72 m.

The total cubic content becomes then:

$$\left.\begin{array}{l}144 \times 5.32 = 766.08\\ 135 \times 1.22 = 164.70\end{array}\right\} 930.78 \times 0.22 \times 0.08 \quad = 16.38 \text{ c.m.}$$

$$\left.\begin{array}{l}144 \times 4.00 = 576.00\\ 135 \times 41.72 = 5632.20\end{array}\right\} 6208.20 \times 0.15 \times 0.06 = 55.87 \text{ c.m.}$$

Total 72.25 c.m.

Recapitulation.—72.25 cubic metres at 80 francs	5780 fr.
2160 square metres, covered with tiles (13 to the metre at 90 fr. per 1000) including laying at 2.50 fr. the metre	5400
600 metres of gutter at 2.50 fr.	1500
Preparation of ground and sundries	520
Total .	13,200 fr.

The cost is thus increased about 30 per cent., and it must not be forgotten that the simple interest on 3200 francs for twenty years at 4 per cent. is 2560 fr., that is to say, about half of the value of the plank roofing, even admitting that it has to be renewed entirely at the end of that time, which is not so.

3. ESTIMATE OF DRYING-ROOMS IN STOREYS (Figs. 176, 177):

TIMBER-WORK.—*Cubic contents of a truss.*

				Joists.	
Posts *H*.			2 of 7.66 m.	34.666 × 4 = 138.66 m.	417.66 m.
			2 of 9.66 m.		
Beams *H*.		1st storey	2 of 5.33 m.	50.66 × 4 = 202.66 m.	
		2nd ,,	1 of 10.66 m.		
			2 of 4.66 m.		
		3rd ,,	1 of 10.66 m.		
			2 of 4.66 m.		
Beam supports	*A*.	4 doubles of	4 m.	16.00 × 2 = 32.00 m.	
Rafters	*A*.	2 ,,	10.66 m.	10.66 × 2 = 21.32 m.	
Tie-beam	*A*.	1 double of	10 m.	10.00 × 2 = 20.00 m.	
King-post	*A*.	1 ,,	3 m.	3.00 × 1 = 3.00 m.	

			Basting.
Small beams	12 doubles of	2 m.	40.66 × 2 = 81.33 m.
Rafters	2 ,,	2.33 m.	
	4 ,,	1.66 m.	
	2 ,,	2.66 m.	

Cubic content of an intertruss.

	Joists.	
Joists: 20 on the 1st, 39 on the 2nd, 29 on the 3rd floor = 88 at 4 m. =	352.00	388.00 m.
Purlins: 9 of 4 m. =	36.00	
	Basting.	
Rafters (0.40 m. from axis to axis): 20 of 11.66 m. = 233.33 m.		

Total cubic contents of 13 trusses and 12 intertrusses.

Joists	417.66 × 13 = 5429.66 388.00 × 12 = 4656.00	10085.66 × 0.22 × 0.08 = 177.507	212.222 c.m.
Basting	81.33 × 13 = 1057.35 233.34 × 12 = 2800.00	3857.33 × 0.06 × 0.15 = 34.715	

MASONRY.

	2 Lateral walls 8 m. high × 48 m. long = 768 sq. m.		1168 sq. m.
	2 Gable-end walls 8 m. ,, × 20 m. ,, = 320 ,,		
	2 ,, ,, 2 m. ,, × 20 m. ,, = 80 ,,		
Less	72 windows in side-walls 32 ,, in end-walls	104 of 2 m. × 1.75 m. = 364 sq. m.	394 sq. m.
	4 doors 3 m. × 2.50 m.	= 30 sq. m.	
		There remain	774 sq. m.

The thickness of the walls being 0.22 m., the cubic contents = 774 × 0.22 = 170.720 cubic metres.

Recapitulation:

212.222 cubic metres of timber	at 80 fr. per cubic metre =	16,977.76 fr.
170.720 masonry	at 30 fr. ,, ,, =	5,121.60
2344 sq. metres poplar-wood planking, 0.035 m. thick	at 3 fr. =	7,032.00
1120 sq. metres of tile roofing	at 2 fr. 50 =	2,800.00
120 metres of gutter, including descent	at 2 fr. 50 =	300.00
104 windows, including glass and paint	at 50 fr. =	5,200.00
4 doors, including paint and fittings	at 100 fr. =	400.00
Sundries		1,168.64
	Total .	39,000.00 fr.

The gross amount of surface available being about 2500 metres, this comes to 15.60 francs per metre.

In the preceding estimates we have taken average French prices; it will be easy, the cubic contents being the same, to calculate prices for any other locality.

4. ESTIMATE OF A GALLERIED DRYING-PLACE.—According to M. Lacroix, who is interested in this kind of installation, the cost of a drying-place sufficient for a daily production of 25,000

bricks is as follows, supposing that they remain *not more than forty-eight hours* (Fig. 178):—

The galleries will contain 50,000 bricks, and require 100 waggons (Fig. 185) holding 500 bricks each; we must add 25 waggons for use outside; hence altogether 125 waggons at 120 francs . .	15,000 fr.
The tunnel, 40 metres long, costs about	5,000
Heating apparatus and accessories	7,500
Rails, turn-table, etc.	2,000
Sundries	500
Total .	30,000 fr.

Besides the cost of installation, the cost of heating must be considered; this varies from 1 to 3 francs per 1000 bricks.

To summarise and in conclusion: storeyed or galleried drying-places with special heating arrangements are necessary for factories which work during the winter. For the latter it is especially necessary that the products should be able to bear a rapid desiccation by a current of hot air, and that the conditions of manufacture allow of regular entrance and exit of the bricks. When this is so, we must calculate whether economy in labour makes up for the cost of heating. For factories which only work during the summer, choice may be made between simple "hallettes" and combined "hallettes." The cost of installation of the latter is greater, and they have less drying power, but they are more easily managed; the expense of tramways is reduced, and there is no danger of injury from the heat of the sun. In brick-making by machinery they are preferable to the simple sheds.

Transport of Products from the Machines to the Drying-sheds.—There are two cases to be considered: (1) when the drying-places are on the ground-floor, on the same level as the machines; (2) when they are in storeys.

(1) *When on the Ground-floor.*—In this case the transport is effected by means of barrows and waggons. The barrows, which are of a special shape, are made of wood (Fig. 180) or of iron (Fig. 181); they consist of an inclined platform on which the bricks are placed, either flat or on edge, in rows separated by spaces of a few centimetres.

When the bricks are made of fairly firm paste, other rows may be placed on the first, but the first must be sprinkled with sand, otherwise the bricks will stick together. Each barrow takes from 30 to 50 bricks, according to their dimensions. The barrows may have one wheel or two.

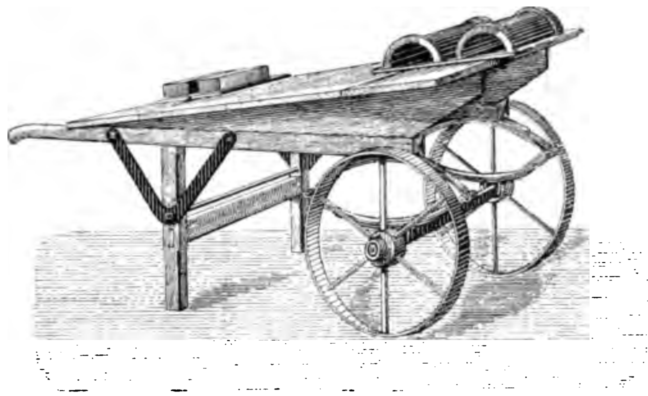


Fig. 180.—Wooden Two-wheeled Barrow for transporting Fresh Bricks (Lacroix).

Whenever the production is fairly large, it is advisable to substitute waggons for barrows.

Rails of 0.40 or 0.50 metre gauge are laid down in the drying-sheds, and at the end of the shed a line of rails is placed, at

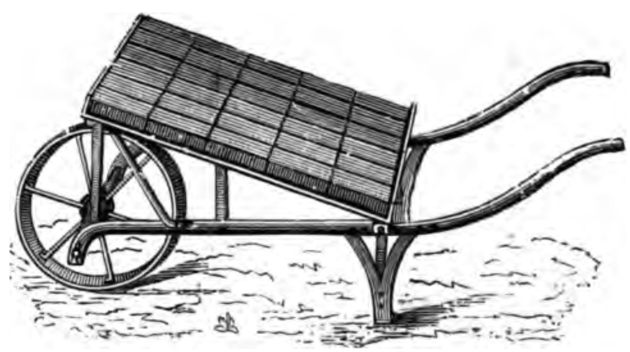


Fig. 181.—One-wheeled Iron Barrow for transporting Fresh Bricks (Paupier).

right angles to the other, and carrying a transfer trolley (Fig. 182), which is more economical and more quickly worked than a turn-table.

This arrangement is particularly advantageous in combined

sheds (Fig. 175); it is at the same time useful for carrying away dry products.

The waggons used consist of a simple framework (Fig. 184) on which is placed a wooden platform. To push the waggon,

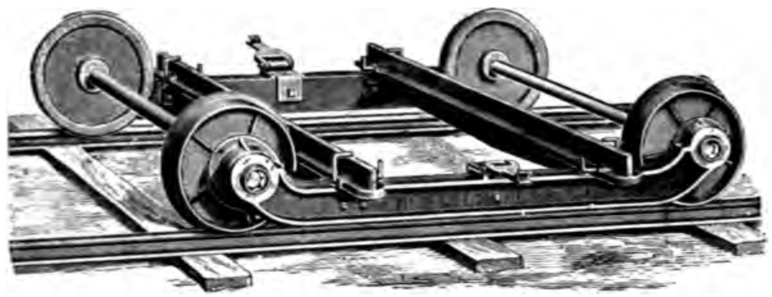


Fig. 182.—Transfer Trolley (Lacroix).

an iron rod is fixed to one end of the frame. The waggons used for transport of dry and fired bricks may also be employed (Fig. 183). The only difference is that these have two sheet-iron ends to the platform. The bricks should be made of fairly firm paste, so that several layers may be taken.

Fig. 183.—Waggon for Transporting Bricks (Decauville).

If soft paste is used for manufacture, it is better to employ waggons with shelves (Figs. 185, 186) which allow of about 500 bricks being carried on planks. These waggons are also useful with cutting-tables with side removal (Figs. 145, 146).

All that is required is to carry the board, with the bricks

on it, from the table to the waggon; labour is thus much simplified.

The same waggons are also used for drying in galleries; the spaces at the centre of the waggon and between the planks allow the hot air to pass and so assist desiccation.

Fig. 184.

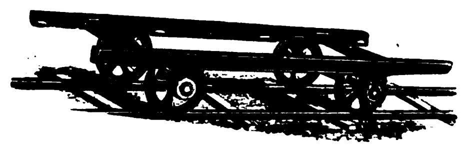


Fig. 185.

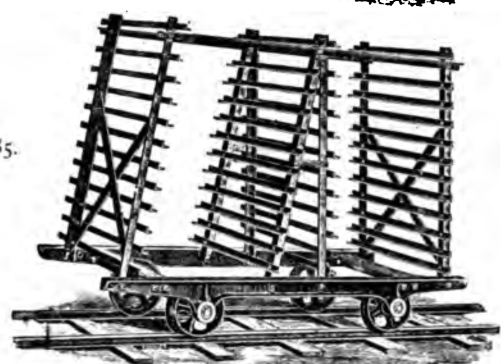


Fig. 186.

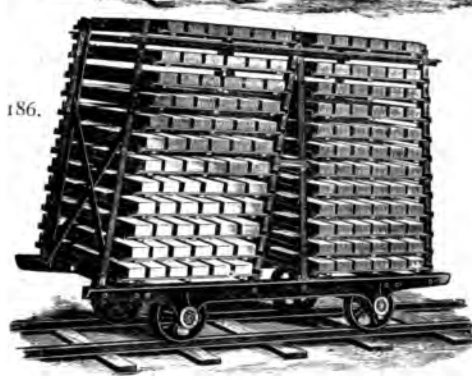


Fig. 184.—Frame of Waggon for carrying Bricks (Lacroix).
Fig. 185.—Waggon with Shelves, empty (Lacroix).
Fig. 186.—Waggon with Shelves, full.

(2) *Storeyed Drying-rooms.*—In this case the products have to be transported from the machines to the different storeys of the drying-sheds. Therefore the use of lifts is indicated. These may be arranged for carrying full barrows and waggons; they are then ordinary lifts of large size. They work satis-

factorily but require much power. Hence it is preferable to use lifts which raise the bricks direct (Fig. 187). On the different storeys boys remove the bricks and place them on barrows or waggons for transport to the various parts of the drying-rooms.

Fig. 187.—Vertical Lift for raising and lowering the Manufactured Products (Bernhardi Sohn).

The trays being hung so that they always remain horizontal, a brick may be overlooked without its upsetting in passing over the top of the lift.

The wheels of the lower drum are adjustable, so that a proper degree of tension can always be given to the endless chain. This lift is placed close to the cutter of the machine, and the bricks are thus passed direct to the trays.

Particulars of Vehicles for the Transport of Bricks.

Wooden barrow, Lacroix (Fig. 180), weighs about 20 kil., carries from 30 to 50 bricks, and costs	50 fr.
Iron barrow, Paupier (Fig. 181), weighs about 33 kil., carries from 30 to 50 bricks, and costs	50 fr.
Decauville waggon (Fig. 183), length 1 metre to 1.40 metres, runs on a gauge of 0.40 m., carries from 150 to 200 bricks, and costs from	90 to 130 fr.
Lacroix waggon with shelves (Figs. 185, 186), carries up to 500 bricks, and costs	112 fr.

(3) FIRING.

The firing of pottery is the most delicate and the most important process in its manufacture. On the success of the operation depends the good quality of the products which have already required so much care and time. For a very long time firing was effected by burning wood in simple ovens, but afterwards coal was substituted for wood in countries possessing mines.

As the means of communication were developed, this substitution became more common, but the method of firing bricks

underwent little change. Nevertheless the old Flemish process was gradually replaced by the use of various kilns which simplified the work, and in 1865 a great step in advance was made by the invention of the continuous kilns of Hoffmann and Licht of Berlin. Since then the substitution of gas for coal heating has been another improvement. We shall divide this part of the subject into several paragraphs according to the various methods of firing bricks:—

1. Firing in clamps.
2. ,, in intermittent kilns { *A*. Open. / *B*. Arched.
3. ,, in continuous kilns { *A*. With solid fuel. / *B*. With gas.

Intermittent kilns are those which are allowed to cool after firing, to permit of the removal of the bricks.

Continuous kilns, as the name shows, are always active throughout the season or even the whole year. The heating and cooling of the products are effected methodically.

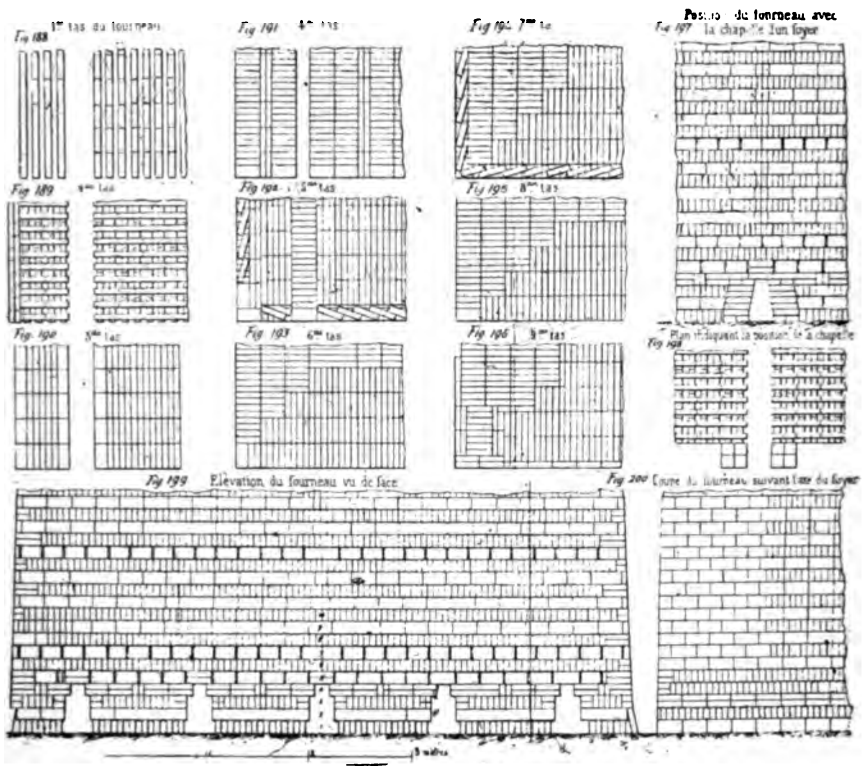
We must not think of describing all the kinds of kiln used; every manufacturer has his own style; but, generally speaking, the differences between the numerous types of kiln are of no great importance. We shall content ourselves with describing one example of each system, specially mentioning those which seem to us most to be recommended on account of their economical working and the beauty of the products obtained.

I. *Firing in Clamps.*

Flemish Method. — This is undoubtedly the simplest method; but it is neither the most economical, nor the one giving the best results. We shall study it in detail because, in an improved form, it is still the one most widely used in the numerous brickworks of moderate importance.

This system consists of placing the bricks in regular layers intersecting one another, and scattering between them finely divided coal, the combustion of which causes the baking of the bricks. In order to ignite this coal the *foot of the kiln* is arranged as follows:—

Upon a smooth piece of ground, slightly elevated so that rain-water may not rest on it, rows of fired bricks are laid down on edge (Fig. 188). The number and length of these rows depend upon the quantity of bricks to be fired, which may be from 200,000 to 600,000. The second layer (Fig. 189), placed like the first, cuts it at right angles, the third and fourth are arranged as in Figs. 190 and 191. At distances of a yard



Figs. 188 to 200.—View of a Furnace, Elevation, Section, and Plans.

are placed furnaces as shown in Fig. 199; they go from one end to the other of the stack, and, before the fifth layer is placed, are filled with wood. Then the vaults are closed, and above, among the bricks, are placed parallel rows of large lumps of coal which will be kindled by the flame from the wood, and by their slow combustion will set fire to the fine coal of which we shall speak later on. When once the foot of the kiln is

finished, the "cuiseur" or stoker proceeds to light the fires. When the coal is thoroughly kindled, the "enfourneurs" begin their work; there may be one or two, according to the size of the stack, and they are assisted by "entredeux," who receive the bricks from the hands of the barrow-men. The "enfourneur," the "entredeux," and the necessary number of barrow-men form a gang. The early part of the work is unpleasant for the "enfourneur," who has to lean continually over burning coal surrounded by the gas and smoke coming from it, therefore he cannot remain long over the furnace; another takes his place, and the work continues. When the *clamp* is finished, the stoker sprinkles finely divided coal over it. This he does with special baskets which are handed to him by the gang; with a quick motion and without stooping he sprinkles the coal in a uniform layer over the bricks. Then in the same way he sprinkles a little sand to prevent the bricks from sticking together. When the operation is finished, the stacking is recommenced, and a new "clamp" is formed at right angles to the first.

When this is finished, it is sprinkled with coal and sand, and another is begun; in this way six or eight clamps are built in a day, according to the progress of the fire.

During the stacking of the bricks, the stoker dilutes some clay, and when the paste is sufficiently liquid, he plasters over the facing of the four sides of the clamp. After the fire is well alight he closes the entrances to the furnaces with bricks, which he also coats with clay. The fissures which form in the clay plaster permit the entrance of the air necessary for combustion.

Besides, if it is necessary at any time to stimulate the fire at a given point, one or several furnaces may be opened again. The fire passes from clamp to clamp, and the skill of the "cuiseur" consists in guiding it as regularly as possible. Experience alone can give the necessary practice, but a few general hints as to the course to be adopted may be offered. We have stated that a slight layer of finely divided coal as uniform as possible is thrown over all the clamps; it is by

this that the fire is communicated. Experience teaches the amount of coal which should be scattered, but the points at which the fire requires to be retarded and stimulated are shown by indications that should be carefully observed. Thus, if we see the bricks of the last clamp becoming white or yellow, it means that the flame is near, and consequently that it is moving too fast in that neighbourhood. Although we might not think so, this will be the place where *more* coal must be added. When, however, no signs of combustion appear, the fire is sleeping, as they say; therefore no more fuel is added. And finally, in order to retard the action of the fire where there is too much activity, not only is much coal added, but the spot is sanded so as partially to fill up the interstices of the bricks. The last clamp built on the previous day should be alight in the morning; this is a sign that all is going well. The "cuiseur" quickly scatters coal and sand, then the "enfourneur" who follows him hastens to make another clamp; but, in spite of these workmen being accustomed and inured to heat, they cannot remain more than a quarter of an hour, sometimes less, and others must take their place.

An equally disagreeable task is the sounding which the "cuiseur" must make every morning to test the degree of baking of the bricks placed the day before. If he finds them too much baked he will consequently diminish the coal; he will increase it, on the contrary, if the firing has not been active enough.

Sometimes several clamps are made "à blanc," that is to say, without coal; this is done when the fire is too violent, or when a change is made from a more to a less strong clay. The number of clamps that can be stacked in a day depends upon the conduct of the fire. If it is active and uniform, seven or eight or even ten may be erected, but if it is not active, we must be careful not to build too many, for the fire would slacken and smoulder, which exposes the bricks to the danger of being burnt by sudden bursts of flame. When, at any point, the fire rises less quickly, its progress is assisted by making one or two less clamps and thus leaving a vacant space which is filled up on the following day.

At the beginning of the day's work, no smoke appears,

because poor coal is used; but at the end, the water from the bricks evaporating forms white vapour, which, if the weather is damp, become so compact sometimes that all work is rendered impossible.

The skill of the "enfourneur" consists in being able to make the facings of the clamp perfectly perpendicular, and especially in placing properly the bricks at the edge, for the clamp rises to six or even seven metres in height, and not only must it resist the pressure of the load, but also that of the fire. This is because the centre, being always more baked than the edges, undergoes less contraction; also, towards the edges, the combustion of the

Fig. 201.—Brick Barrow (Whittaker).

coal is less complete than in the middle, and the effect of all these causes is that the subsidence is more marked here than in the facing. This inconvenience must then be remedied.

To raise the bricks on to the clamp, special wooden or iron barrows called "brouettes à barque" are used.

The clamp is ascended by means of inclined planes formed of planks resting on trestles, which are raised every day; a second but steeper plane is used for bringing down the empty barrows. Planks are also placed on the bricks for the barrows to run on, and are taken away in the evening. When the clamp has reached the required height, it is covered with a bed of clay

which will become baked while preventing the heat from leaving the upper layers too soon. This clay, when crushed and passed through a sieve, will be used by the moulders for powdering their moulds.

Accidents during Firing.—When the weather is fine, the brick dry, and the stoker skilful, there are no accidents; but the inclemencies of the weather, rain, wind, etc., have to be considered.

To guard against the wind, screens are constructed with poles and straw matting, but this does not prevent the gusts of wind which pass over the top and drive back the flame. The latter concentrates and endeavours to escape, thus causing inflation of certain parts of the facing. The furnaces must be at once opened, and if that is not enough, the clay coating must be at once torn down in order to avoid a breach likely to cause serious accidents which would damage the firing and might even ruin the whole mass.

As for rain, it is difficult to avoid its bad effects; if it threatens in the evening, sand and coal are added to protect the surface of the bricks. If it falls when the fire is near the surface, no great harm is done. But if it comes on towards the end of the day, that is to say, when the fire is at some distance, it may cause, according to its violence, the loss of one or two clamps, which will then have to be removed, sometimes with shovels if the bricks are softened.

Waste and Quality of Bricks fired in Clamps.—The waste is enormous and the quality of the bricks is poor. The waste is explained as follows:—

Let us suppose a mass of 500,000 bricks divided into 60 clamps of 8000 each. First 50,000 bricks will have to be used for building the furnace, which must be rebuilt every time. It is true that these bricks can be used again, but some will naturally have to be renewed. We will estimate these at . . 5,000

There are always two or three layers at the bottom not properly baked, say two of 8000 each	16,000
At the top the same thing occurs to three or four layers of 8000 each, say	32,000
Finally, the facing bricks are badly fired, and we may estimate them at .	27,000
Which makes a total of .	80,000

even admitting that the whole interior is well fired, which is not always the case; for we must account for sudden bursts of flame, welding together several bricks, and for too quick spread of fire, causing the bricks to be too little fired. The quality of the bricks is very mediocre, firstly on account of these irregularities in firing, and secondly because it is impossible to bake bricks well without causing accidents called "loupages," which consist of a dilatation of the brick if the fire has had only a violent passing effect, and of fusion if the action has been prolonged. The slag of the coal and sand become strongly attached to the bricks, and cannot be detached, even by energetic washing, and this is called "grésage." It prevents bricks fired by this method from being used for well-finished facings.

Expense in Fuel.—This is very difficult to estimate, as it depends upon variable conditions, such as the quality and price of coal, the nature of the clay to be baked, the skill of the stoker, state of the weather, etc.

Generally poor coal is used, giving a steady fire without sudden outbursts, and smokeless. Often any kind of coal is used, and passed through a sieve; the remaining slack is used for the firing at the foot. Approximately, 130 to 160 kilos of coal are burnt for every 1000 bricks kilned of the dimensions 0.22 × 0.11 × 0.06. We must not forget that the very perceptible waste (at least 15 per cent.) increases this quantity, and that the bricks receive a poor firing, not nearly as strong as that given by continuous kilns.

II. *Firing in Intermittent Kilns.*

A. **Open Kilns.**—In order to obviate certain defects in clamp-firing, especially the construction of the foot, and the large waste, bricks are baked in kilns which ensure a more regular firing with less loss.

One of the simplest kilns is represented in Figs. 202 and 203. In order to economise masonry, and also to resist the pressure of the fire which is particularly noticeable in the lower part of kilns, they are partly made of clay. The foot of the kiln or gridiron, which is pierced with a large number of square

holes, rests on Gothic arches, called "arches," three in number. They are formed of a certain number of vaults, between which are openings communicating with the three squares of the gridiron. These vaulted galleries serve for the passage of air, and for setting fire to the foot of the kiln by means of wood which is burnt on the pavement of their floors. One or two holes made in the wall, and closed during the firing, give entrance to the kiln.

OPEN INTERMITTENT KILN.

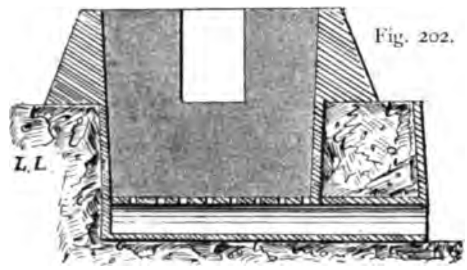


Fig. 202.

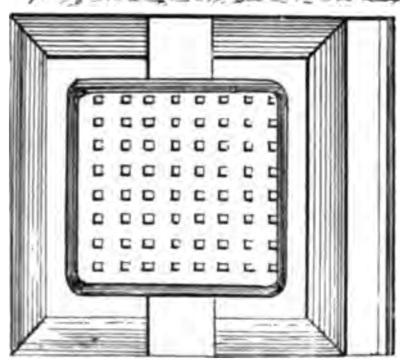


Fig. 203.

Fig. 202. Longitudinal Section. Fig. 203.—Plan.
(Scale of 4 millimetres to the metre.)

Wood or coal is used as fuel. The part in front of the kiln, called "avant-four," is generally below the level of the ground; hence, in order to avoid the collection of rain-water which would invade the kiln, a deep well is dug and filled with large stones.

1. FIRING WITH WOOD.—The kiln is filled with bricks, each layer being separated from the next by sand. The method of filling the kiln is variable, but in kilns holding from 100,000 to 120,000 bricks, about one-half are stacked solid, that is to say,

the bricks close against one another in the mass, vertical chimneys being reserved corresponding to the holes in the gridiron. The rest of the bricks are packed loosely, that is to say, the chimneys are omitted, but a certain interval is left between the bricks; the layers cutting one another at right angles, the bricks are always placed on edge. It is well to put at the bottom of the kiln the bricks which will undergo the least contraction, and which best resist heat; that is to say, those made of strong clays, on account of the weight of the mass which they support.

As filling the kiln takes time, and rain may cause damage,—for no fire will guard against the moisture caused by it,—the kiln is covered with a wooden roof which is taken off before firing.

When the kiln is full, we place on the raw bricks a row of baked bricks laid flat and called "platin," then the fire is lighted on the floor of the subterranean galleries called "arches" or "cloches," and is very gently pushed; this is the period of the "petit feu" during which "enfumage" takes place, that is to say, the removal of the hygrometric water still left in the brick.

The "enfumage" being finished, we pass to the "grand feu," which is obtained by actively pushing forward combustion night and day. When the mass begins to turn red, the draught is lessened by covering the "platin" in places with damped clay, especially where the fire is rising too quickly. The progress of the firing is followed by measuring the contraction by means of fixed marks. The fire is kept up near the orifice of the "cloches," and the draught suffices to distribute the heat throughout the kiln; nevertheless, in order to ensure a uniform baking, some fagots are from time to time pushed down into the vaulted galleries with long pokers; this is what is called "pousser au fond."

Sometimes soot fills the chimneys and obstructs the draught. It will be sufficient to let it burn itself out by diminishing the fire in the vault corresponding to the obstructed chimney. From day to day the upper part is more plastered to concentrate the fire in the mass. When a certain degree of contraction is reached, —not the total contraction, for the firing mass will continue to

diminish in volume,—the orifices of the "cloches" are stopped up, the top of the kiln is covered with a thick layer of clay, and it is allowed to cool. Wood-firing gives excellent products, well coloured and ringing well, but it is troublesome and difficult to work. For fuel, fagots are used, or, more economically, brushwood.

Cost of Firing.—It is as difficult to estimate, if not more so, than in the case of coal. With brushwood at 15 francs the hundred, however, it may rise to 8 or 10 francs per 1000 bricks. The waste is not great *if the kilning is well done.* In the chimneys bricks are found which are black and varnished; this effect is due to soot and the fusible products contained in it, which become attached to the bricks when heated to a red or white heat.

2. FIRING WITH COAL.—(1) *In Clamps.*—This is carried out in exactly the same way and with the same care as by the Flemish method. To guard the bricks from rain and wind, a shed is built over the walls of the kiln with a tiled roof high enough to leave unhindered the progress of the firing and the disengagement of gas and vapour.

When several ovens are close together, a movable roof is sometimes constructed which runs on flanged wheels guided by rails placed on the walls of the kilns. When the weather is fine, this roof is pushed over a kiln not in course of firing; if rain comes on, it is brought over the active kiln. In spite of these precautions it is difficult to bake in these kilns during the winter on account of the inclemencies of the weather, which cause loss and render the work troublesome and sometimes impossible; this is because the bricks have to be transported across the open from the sheds to the kiln, and also because much smoke, due to the moisture, is produced as soon as one or two clamps are laid.

Generally two kilns are built one against the other, and this is simply done by dividing a single large kiln into two by a thick wall. The capacity of these kilns is very variable. There are some which can bake as many as 400,000 bricks, but these large kilns are less convenient than those holding 150,000, on account of the enormous number of raw bricks which must be accumulated. The number of kilns in a brick factory depends

upon its importance, but there must be at least two, for the bricks are taken out as they are wanted for sale; and if none were being fired while this was being done, the factory would find itself without goods, the kiln being empty.

(2) *By Flame.*—That mode of firing called "à la flamme" is carried out in a kiln like the foregoing one, but, instead of burning coal placed in thin layers between the bricks, combustion takes place on fire-bars placed in front of the kiln. The fireplaces are three or four in number, and are fixed, each grating being about two yards square. These kilns are not recommended, for, under such conditions, it is better to use covered ovens.

B. **Vaulted Kilns.**—Open kilns lose a considerable part of the heat formed by combustion of the coal or wood. Generally the upper part is badly fired; moreover, the wind and rain, in spite of a protecting roof, have an injurious effect on the progress of the fire. To avoid these disadvantages it has been found advisable to close the kilns by an arched roof which shelters the fire from the influence of the elements and throws back the heat on to the products before it is lost in the air.

These kilns are divided into—

1. Kilns with direct flame ((1) Rectangular; (2) Round).
2. Kilns with reversed flame.

1. **Kilns with Direct Flame.** — (1) RECTANGULAR. — In these, the furnaces are placed according to the greatest length of the kiln; above is a flooring pierced with a large number of holes which communicate with the oven. The upper vault is pierced with holes communicating with channels which lead to the chimneys, for the escape of the smoke and gas when they have produced their effect. A single chimney may serve for several kilns, and often the draught is produced without any chimney at all.

The method of filling these kilns depends upon the kind of bricks to be fired. For those which bake at a relatively low temperature, the bricks are arranged so as to spread the flame over as large a surface as possible; that is to say, they are separated about a finger's breadth from one another; the rows or clamps are crossed and inclined to one another, to ensure the

solidity of the mass and at the same time divide the flame by forming "chicanes."

The firing begins with the "enfumage" or period of "petit feu," then when all trace of moisture has disappeared, the "grand feu" begins, which is the period of baking. The fuel used is wood, peat, coal or coke, according to locality. The coal should be of a kind giving a long flame; its use exposes the products more easily to sudden outbursts of heat than wood, the heat of which is always uniform; but cost should decide in these questions, unless delicate objects have to be baked, in which case wood should be used.

The longitudinal channels lead into a single transverse

COVERED RECTANGULAR KILN.

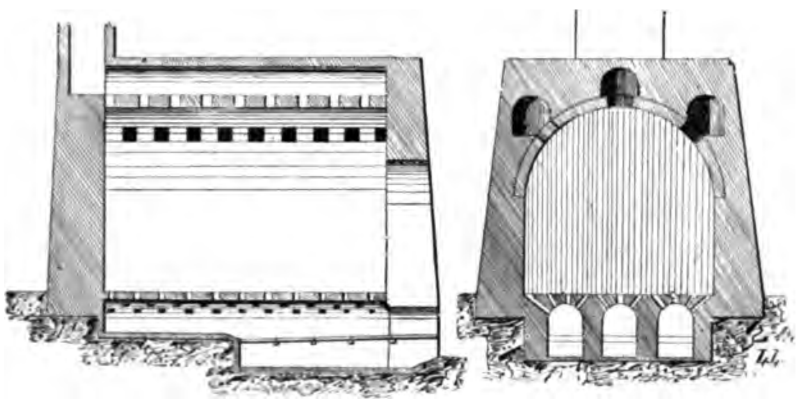


Fig. 204. —Longitudinal Section. Fig. 205. Transverse Section.
(Scale of 1 centimetre to the metre.)

channel opening into the chimney. Registers are placed in each channel, so that the fire can be pushed at points where firing is progressing less quickly. Openings in the vault permit of the degree of contraction, and consequently of firing, being observed.

In other kilns there is no pierced flooring, and the three furnaces are placed in front of the kiln, as in the case of open kilns firing "à la flamme." This arrangement is defective; for there is danger of burning the products placed in front of the fire-bars, and very often those at the end of the kiln are not baked at all.

(2) ROUND KILNS.—The furnaces in these are arranged round the products to be fired. Their number depends upon the size of the kiln. It is more easy to get a uniform firing with these than with the foregoing, for there are no corners into which, very often, the flame does not penetrate. Their round shape gives them a great resisting power which, in many cases, renders unnecessary any iron plating.

2. **Kilns with Reversed Flame.**—In the preceding kinds, the combustion gases and the flames from the furnace reach the chimney by the shortest path. The products to be fired must then be on the direct route. This condition is not always easy to fulfil, and hence it happens that bricks which are not reached remain insufficiently baked, and there are inequalities in the firing.

To obviate this inconvenience and to get a uniform baking of the products, kilns with reversed flame, as it is called, have been constructed. These may be built square or round; the latter form is the better, and should always be preferred. Many examples of this type are known, but their principle is always the same. The furnaces are arranged round them, and are sufficient in number; the arch of the kiln has no orifice; the flooring is pierced with holes which communicate with a circular channel leading to a chimney.

The flame penetrates into the oven and ascends to the arched roof; finding no outlet there, it is forced to descend again towards the bottom, whither the draught attracts it.

In this movement currents are produced which effect the mixture of various warm gases in such a way that a uniform heat reigns throughout the whole interior of the kiln. Moreover, the vault produces an intense radiation which allows of a very high temperature being attained. Thus these reverberatory kilns are used in the firing of stoneware and similar products requiring great heat.

We have introduced some modifications into these kilns with the object of rendering them more easy to fill and more economical in fuel. The furnaces are placed in the thickness of the wall and arranged as gas-generators, the air necessary for combustion being warmed while passing through the "chicanes"

which are on each side of the furnace. Figs. 206 to 211 are sections and plan of this kiln.

The dimensions of reverberatory kilns cannot exceed a certain limit, on account of the too great height which they would reach. We shall take as maximum a cubic content of 100 cubic metres (40,000 to 50,000 bricks), which corresponds to a diameter of 6 or 7 metres and a height of 4 or 5 metres. This height has less disadvantages than in the case of continuous kilns, for the best baked bricks are at the top, while in the Hoffmann kilns it is generally those at the base which are most fired, and the considerable contraction which they undergo causes movements in the mass which often deform the bricks. Therefore it is recommended that the height of continuous kilns should not exceed a certain limit. It is evident that small kilns are, proportionately to their size, dearer and less economical than large ones.

In the foregoing kilns which burn coal on fire-bars, the latter are of small or large section. Gratings of large section are particularly suitable for rectangular kilns (Figs. 204, 205); it is calculated that 0.350 kilos (about 12 ounces) of coal per hour are consumed for each square decimetre (about 15 sq. in.) of the fire-bars. For gratings of small section this quantity may be estimated as high as a kilogram (2.2 lbs.); it is always better to have too large gratings, for it is easy to diminish their section by covering them with bricks.

The section of the chimney ought to be larger than for an ordinary grating, for, besides the products of combustion, the water-vapour given out by the green bricks has to be carried away. Reverberatory kilns require especially a strong draught to bring down the flames, which have a tendency to remain under the roof. Some manufacturers give a chimney to each kiln, others build one only for a combination of four or six kilns. In this latter case the kilns are connected by air channels provided with trap-doors or registers to give the firing a kind of continuity. The burning gases of one kiln at full heat help to warm the next one, which is already red when its furnaces are lighted, the following one being "en enfumage." If this

REVERBERATORY GAS KILN. (Scale of 15 millimetres to the metre.)

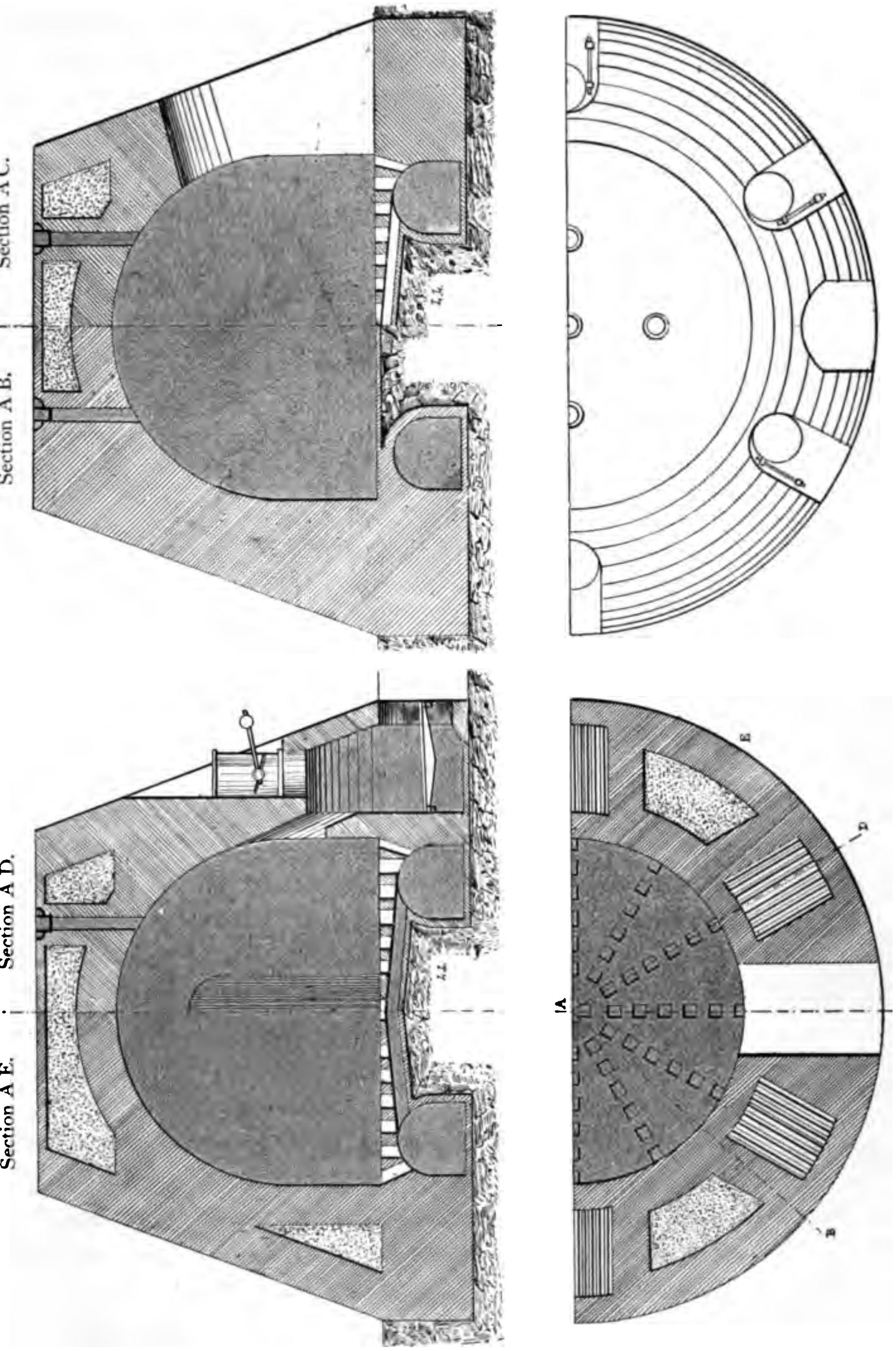


Fig. 206.— Section A E.

Fig. 207.— Section A D.

Fig. 208.— Section A B.

Fig. 209.— Section A C.

continuity should happen at any given moment to hinder the progress of the fire, it would be easy to stop it by altering the registers so as to connect the kilns directly with the chimney.

It is difficult to estimate the consumption in covered kilns, with direct or reversed flame; it depends, in fact, on many circumstances: nature of the products, degree of baking, mode of stacking, management of the fire, and draught, all of which have a more or less important influence on the final result.

Progress of the Fire in Intermittent Kilns.—Whatever the form of these kilns may be, the fire is always oxidising in them during the filling of the kiln and at the beginning of the "grand feu," for during these periods the quantity of fuel is small in comparison with the air entering by the open doors, and the latter is in excess in the products of combustion. But during the "grand feu" the doors of the furnaces are closed, and air is no longer in excess, especially at the end of the firing, when all the combustible gases are not always completely burnt. The firing then begins in an oxidising atmosphere and concludes in a reducing one.

Covered kilns make better use of the heat than open kilns, and they allow of the products being well fired, especially round reverberatory kilns. But the loss of heat is still considerable, for the gases go to the chimney conduit at the temperature of the baked products, that is to say, at a high temperature.

For a long time attempts had been made to use this waste heat for warming cold products by placing two or three communicating kilns side by side. While one of these was in full swing, its neighbour received the hot gasès, which produced "enfumage" and raised its products to the early red stage, so that, when the first kiln completed its firing, the second immediately entered on the "grand feu" stage, while the third was "en enfumage." There was lacking in this system the principle of continuity, which has been introduced into brick-firing by MM. Hoffmann and Licht of Berlin.

On the Choice of an Intermittent Kiln—Net Cost.—Before describing continuous kilns we will estimate the cost of the different kilns which we have just described. To speak frankly, only one of these is to be recommended,—the reverberatory round

kiln. In France this is reserved for the firing of porcelain, of faïence, and stoneware, but in the United States of America it is extensively used for all kinds of pottery.

A model built by Mr. Pike (of Chenoa, Ill., U.S.A.) is recommended in France by M. Lacroix, grantee of the American maker. M. Chambrette-Belon also recommends a kiln of this system. As we have said, anyone is free to build a kiln of this kind as he wishes, the patent having expired.

All the types offered by different builders only differ in detail.

In the following estimates, we shall make the same remarks as to the prices we take, as we have already done in speaking of drying-places (p. 182). For purposes of comparison, and in order to show the differences more clearly, we shall suppose a baking of five to six millions of bricks per annum.

Estimate of an Open Intermittent Kiln (Figs. 202, 203).—We shall make this estimate for two kilns placed side by side and each containing about 160,000 ordinary bricks, which corresponds to a cubic content of about 312 square metres with the following dimensions: height 6 metres, length 8 metres, breadth $6\frac{1}{2}$ metres.

Earthwork, 850 cubic metres at 1 fr. 50	= 1275 fr.
Masonry, 250 cubic metres at 30 fr.	= 7500
Sundries	= 225
Total	9000 fr.
Roofing of kilns	extra.

Note.—The kiln being built on the brickworks, it often happens that the clay extracted is used for making the bricks, which diminishes the cost.

For filling, cooling, and discharging such a kiln, about three weeks will be required: supposing work to continue for seven months, that is to say, 210 days, it is seen that 10 charges can be fired in the same kiln, *i.e.* 16,000,000 bricks: we must have, then, at least four similar kilns to reach the desired six millions.

The cost will then reach twice 9000 francs, which was the price of two adjoining kilns, that is to say, 18,000 francs, not

including the sheds which shelter the kilns and assist the work of stacking.

ESTIMATE OF A REVERBERATORY KILN (Figs. 206 to 211). —We shall take a kiln 6 metres in diameter and 4 in height, giving 84 cubic metres of space and corresponding to 40,000 or 42,000 bricks.

Earthwork, 80 cubic metres at 1 fr. 50 =	120 fr.
Masonry, 200 cubic metres at 30 fr. =	6000
Fire-bars, furnace doors, etc. . .	380
Total .	6500 fr.
Roofing of kilns	extra.

A fortnight is taken for filling, cooling, and discharging; a single kiln will then fire annually from 800,000 to 1,000,000 bricks (the kilns being covered and working nearly all the year round).

We shall then want six similar kilns to fire six millions, and

6 × 6500 =	39,000 fr.
A chimney 30 to 35 m. in height	5,000
Conduits, registers, etc. . .	1,000
	45,000 fr.

not including the building in which the kilns stand. As we shall see, a continuous kiln costs less and has as good a production, and the reverberatory kilns should be reserved for small works producing a million to two million bricks. In this case the cost of one or two kilns and their chimney will not exceed 10,000 to 16,000 francs.

III. *Firing in Continuous Kilns.*

The principle of the continuity of firing was stated by Péclet, in his *Traité de la Chaleur* (3rd ed., 1860), and various practical applications of this principle had been carried out successfully by Muller and Gilardoni, when Hoffmann and Licht gave to continuous kilns the definite form which made a success of them.

With these kilns only can be completely acquired what had

been already sought for in covered and combined intermittent kilns; that is, the utilisation of the excess of heat necessary for firing for the gradual heating of the objects kilned. In continuous kilns the heating is methodically carried out, that is to say, the warm gases after having effected firing are cooled by passing over cold products in the kilns and escape into the chimney carrying a minimum of heat with them. On the other hand, the air necessary to combustion is strongly heated while passing over fired products which are cooling.

Two processes ensure the continuity of the fire while fulfilling the above conditions: one is to have a fixed furnace to which the products are brought to be fired, and from which they are, after firing, removed; the other is to alter the position of the furnace with respect to the bricks which remain stationary.

The first system does not appear to have reached a practical stage in spite of the ingenious attempts of M. Demimuid and MM. Boulet frères, who thought of making waggons, covered with refractory clay and filled with bricks, move before a fixed furnace.

The excess of heat was used to warm the waggons in front.

In M. Barbier's kiln, the reverse took place: the furnace, mounted on a waggon, was moved and came to bake in turn the different batches of bricks arranged in a fixed kiln.

The use of these machines, which date from 1855, has been prevented by various causes, especially the maintenance of the rolling-stock and certain practical difficulties, but more than all by the appearance at the Universal Exhibition of 1867 of the continuous kiln of Hoffmann and Licht, which was to recommend itself to the pottery trade by its logical principle and the excellence of its results, from the point of view of economy as well as of the beauty of the products obtained.

For the last thirty years it has come more and more into use; if its form has been modified in order to simplify its construction, and if some details have been altered, its principle and fundamental arrangements have remained the same. But a new advance has been made. In the Hoffmann and Licht kiln, the firing is effected by a solid fuel which is thrown upon already

red-hot bricks and there ignites. It has been thought that the system of gas-generators might be applied to continuous kilns, and that the firing of the products might be effected by the burning of the gas; this presents certain advantages, such as the absence of ashes, the great regularity of the baking, and the high temperature which can be reached. After many attempts a satisfactory result has now been attained, and continuous kilns heated by gas will certainly come more and more into use when their working is rendered quite easy and some practical difficulties are overcome.

Continuous kilns are divided into two classes—

A. Those with solid fuel.

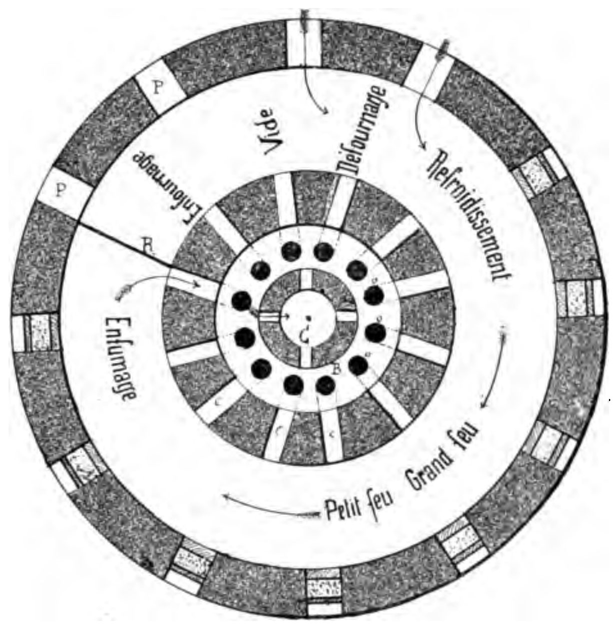
B. Those with gas fuel.

A. CONTINUOUS KILNS WITH SOLID FUEL.—*Hoffmann and Licht Kiln.*—As this kiln is no longer constructed of the primitive round shape, and as the rectangular form given to it by M. Simon, M. Hamel, and others, has been preferred, we will show its working by the diagram in Fig. 212.

The kiln consists of a circular tunnelled gallery called *firing-chamber*, which communicates with the exterior by means of doors, P P (there are twelve in the diagram). These doors are used for charging and discharging, and are hermetically sealed during firing; the distance between them is called a *compartment*. The gallery also communicates by conduits, *c c*, with a circular channel B, which leads direct to the central a chimney C. The orifices, *o o*, by which the conduits open into the central channel, are closed by covers or traps which can be raised at will by some kind of mechanism: screw, chain, pulley, etc. All these traps being lowered, there remains no communication between the gallery and the chimney; if one of them be raised, a draught is established through the conduit leading to that trap.

The arched roof of the gallery is pierced with a certain number of holes closed above by cast-iron stop-valves which fit into a groove filled with sand and hermetically joined. These holes are intended for the passage of the coal, which, when cast upon the red-hot bricks, will ignite on contact and bake the mass.

Let us now consider how the kiln works. We will suppose it to be in full swing. At a certain point in the gallery is a sheet-iron or paper register, R, fixed against the kilned brick and closing the gallery completely. On one side of this register the gallery is filled with bricks, on the other side is an empty compartment where raw bricks are being placed; the following compartment is quite empty, and the third, still on the same side of the register, is being discharged; thus, of twelve compartments, there is *one* empty, *one* being discharged, *one* being



212.—Horizontal Section of the Hoffmann Kiln, showing how it works.

charged, and *nine* full of bricks and with doors closed. Of these nine, three are fired and are cooling, one is "en grand feu," namely, the one which receives the fuel by chimneys or heating wells arranged in the mass of bricks and corresponding to the holes pierced in the roof. In these chimneys have been placed bricks "en chicane," which, by scattering the coal throughout the height of the mass, prevent it from accumulating at the bottom of the wells.

The air necessary for combustion passes over the products

which are already baked, hastens their cooling while gaining heat itself, and arrives over the coal at a high degree of temperature. In this way there is no loss of heat; the gases of combustion, mixed with the excess of air, continue their way after having baked the products, and heat the bricks in the compartment next to that "en grand feu" sufficiently to make them red-hot: this is the place where it is "petit feu." The gases, partially cooled, meet colder and colder products, to which they still yield a certain quantity of heat, and this produces "enfumage," that is to say, the removal of the water always contained in raw bricks, however dry they may be. Then they reach the register R and penetrate into the channel B, which brings them to the central chimney C.

Cooling and heating are therefore progressive, which offers great advantages in the firing of pottery, and the heat of the fuel is as completely utilised as possible; the only important loss is the heat given out by the cooling products, a small part of which only is carried off to warm the air necessary for combustion. We have seen that this waste heat has been used for warming the drying-rooms, which are often placed over the kiln.

When the "grand feu" compartment is fired, and this takes from twelve to twenty-four hours according to its size, they pass on to the next; at the same time the draught is stopped, for the compartment which was being charged has been filled while that "en grand feu" was firing. The door of the compartment is closed and a new register applied against the brick; when it is placed in position, the first is taken out through the door (formerly it used to be removed through the roof, which had an opening for the purpose), or is burned when it is made of paper, which is most frequently the case. The open trap is then lowered and the next one opened.

The motion continues in this way, the fire being moved one or two compartments every day; on the twelfth day it is in the same place again.

The circular form adopted by the inventors presents certain disadvantages: it is costly on account of the considerable volume of masonry and sand that it requires, and of its delicate construc-

tion. Therefore the shape was first modified into an oval, and finally it was made rectangular. These modifications have been praised in turn by Hamel, Simon, etc., who have given their names to the kilns thus changed by them. One of the best known is the kiln devised by the last-named, and we shall give a description of it with the help of Figs. 213, 214, 215, 216, and 217.

RECTANGULAR KILN.—This is composed of two parallel galleries in the form of tunnels with slightly elliptical arch, joined at the ends by a channel (Fig. 217). The arrangement of the doors for filling and of the heating holes in the roof is

CONTINUOUS RECTANGULAR KILN. (Scale of $7\frac{1}{2}$ millimetres to the metre.)

Built by MM. Toisoul and Fradet.

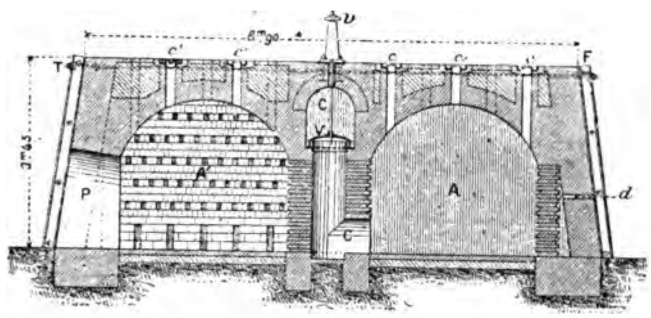


Fig. 213.—Transverse Section E F G H I J.
The Gallery A′ is full of Bricks, the Gallery A is empty.

the same as in the circular kiln, but the escape of the gases of combustion and consequently the draught are effected in a different way. A central channel (3, Fig. 215) situated between the two galleries stretches the whole length of the kiln. It is put in communication with the compartments by vertical channels, *c*, closed by cast-iron traps or doors, V, which are worked from the outside by means of the flywheels *v*, which turn a threaded rod in a fixed nut. The central channel, C, leads to the chimney, either directly, when it is at the end of the kiln, or by a subterranean channel when it is at some distance from it, as shown in the plan (Figs. 217, 215).

Shape and Dimensions—Number of Compartments.—The most

convenient shape for the galleries is the rectangular covered by an arched, or slightly elliptical (Fig. 213) roof. The dimensions of these galleries are very variable; they depend upon the daily production, and the extreme limits of section are from 3 to 10 square metres, and of cubic space from 8 to 60 cubic metres; these are exceptional cases, which it is not always advantageous to adopt. We may take as a good average 20 to 40 cubic metres, that is to say, a space containing from 10,000 to 20,000 ordinary bricks.

The cubic contents of the compartments in the kiln shown in our plans are 28.7 cubic metres, a space capable of accommodating 13,000 bricks. Its dimensions are: 3 metres broad, 4 metres long, and 2.7 metres high under the arch. This height may be reduced without any inconvenience by increasing the breadth.

As to the number of compartments, the minimum for satisfactory progress is sixteen. It is better to have twenty or even more, for the work is then easier; the heat is less strong during charging and discharging, on account of the distance of the fire and the longer period of cooling that the products undergo after being fired. Kilns have even been constructed with a sufficient number of compartments to have one "en grand feu" in each gallery, and this means thirty-two compartments. On account of the length of such a kiln, it may be advantageous to make two of it, side by side.

Nature of Materials to be Used.—Kilns are generally built of brick with or without iron plating. Armoured kilns, like the one of which we give the plans, are very solid, very elegant, and do not take up much space; but they are costly. Therefore it is more economical to support the inner walls with pillars and a thick layer of rammed clay covered with a masonry facing. Thus constructed, the kiln resists fire well and costs less than with plating. To bake ordinary products it is not necessary to make the interior of refractory clay; it will be enough to choose bricks which resist a strong firing well.

But if a high temperature has to be attained, it is absolutely necessary to build an inner covering of refractory bricks.

CONTINUOUS RECTANGULAR KILN. (Scale of 5 millimetres to the metre.)

Built by MM. Toisoul and Fradet.

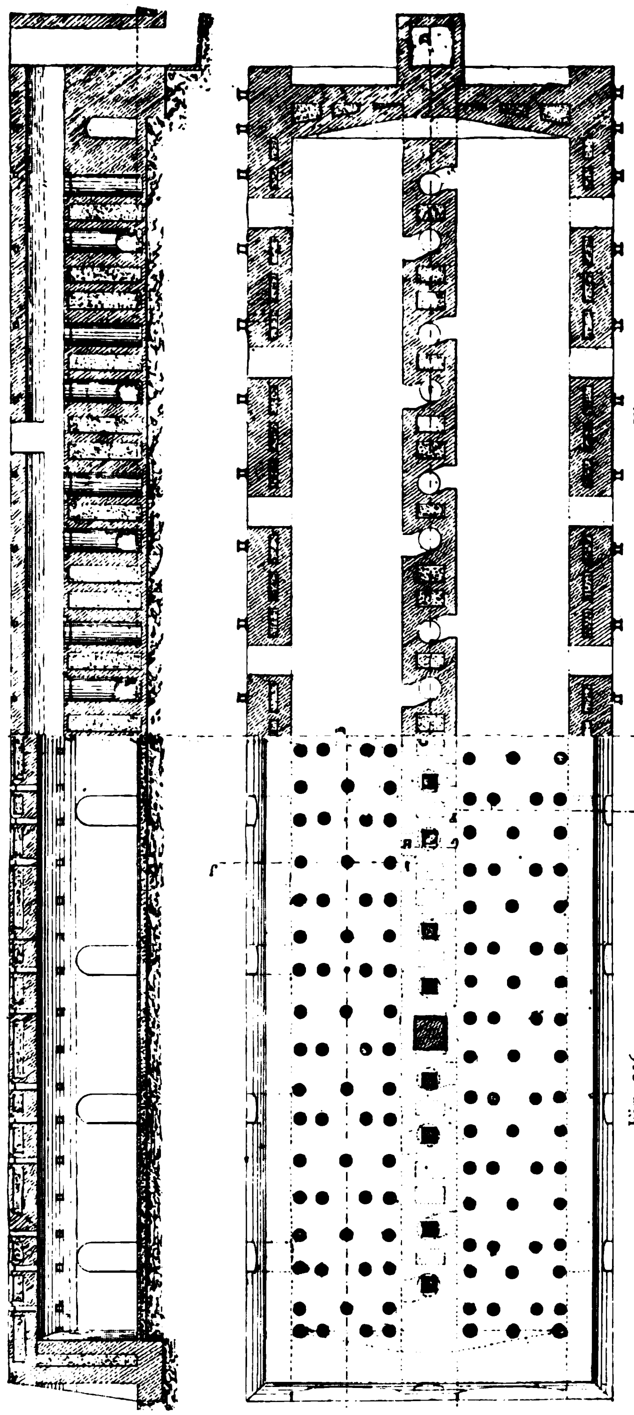


Fig. 214. Fig. 215. Fig. 216. Fig. 217.

Fig. 214.—Section A B. Fig. 215.—Section C D. Fig. 216.—Plan of Top. Fig. 217.—Horizontal Section.

The volume of masonry depends upon the size of the kiln, but it is not proportional to this size, because a small kiln requires, for its size, a greater volume than a large one, and it is more advantageous to build a medium-sized kiln than two small ones.

Arrangement of the Heating Holes.—As these are a cause of weakness in the arch, and as it is always they which cause deterioration in it, we must avoid multiplying them unduly, and content ourselves with the number necessary for good firing. We may say that, for a horizontal surface of 12 square metres per compartment, 12 to 14 holes are amply sufficient for firing even difficult products. The arrangement of them varies, and depends upon the method of firing and of filling the kiln.

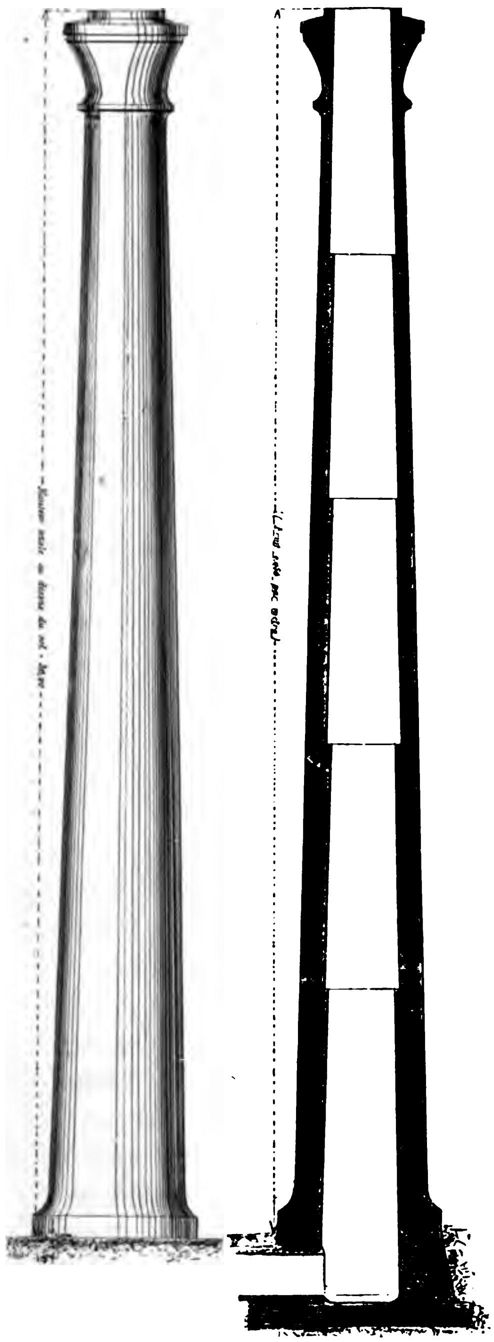
Without being positive,—for in these questions special conditions are of every importance,—we may say that the symmetrical arrangement is as good as any other recommended by builders. Nevertheless it is right to place the holes near the central channel a little farther from the side than those along the outside walls, because the fire always advances more quickly against this channel than against the outside wall, in consequence of the cooling which this latter undergoes, and also on account of the draught which acts on the slope.

Chimney.—This in some kilns is in the very centre of the building, in others it is at one end; the collecting channel opens into it, and this causes some loss in draught owing to the height of this channel above the ground.

As the chimney represents a certain expense which is not much increased by making it large enough to serve two kilns, it is advisable under these circumstances to place it in the axis of separation of the two kilns. It is an advantage to have a strong draught which can be moderated, while on the other hand it is difficult to remedy a deficiency in draught. Some manufacturers prefer a chimney to each kiln, fearing lest the progress of one should hinder that of the other, if one chimney only is used.

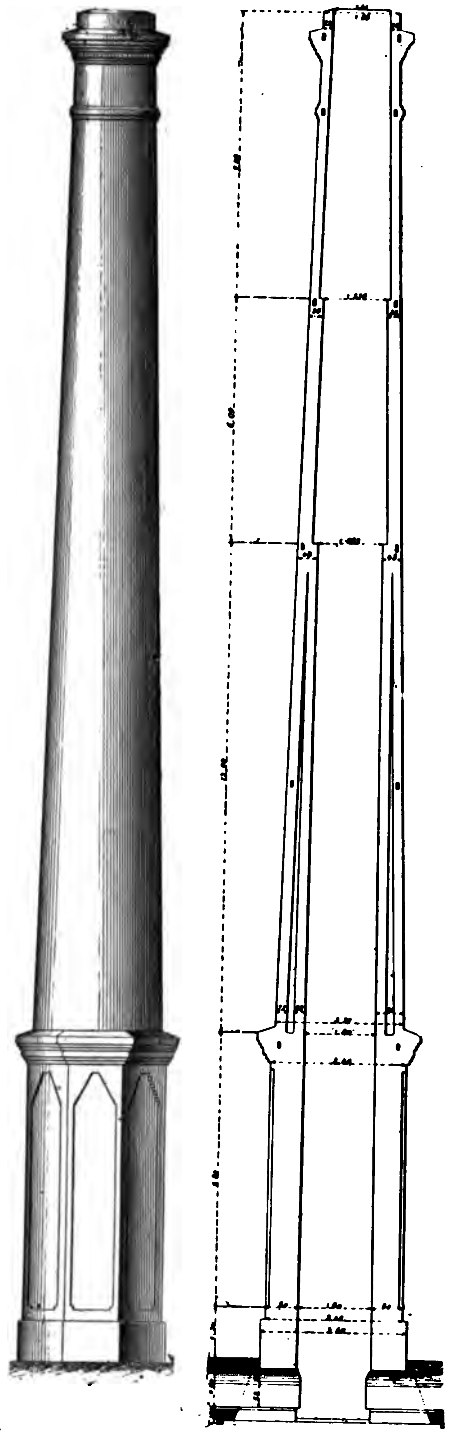
As for dimensions, it must not be forgotten that it must remove not only the gaseous products of combustion but also the water-vapour contained in the products to be fired, which is considerable in quantity.

CONTINUOUS KILNS—CHIMNEY.



Elevation. Section.

Fig. 218.—Chimney (Scale of 5.4 millimetres to the metre).



Elevation. Section.

Fig. 219.—Chimney with Pedestal.

We give (Fig. 218) the plans of a chimney which we have constructed for the kiln just described. The orifice at the top, 1.4 metres across, is sufficient for the draught of two kilns. The Figs. 219 represent another chimney which may also serve two kilns.

Working of the Kiln—Stacking—Heating Wells.—The first thing to be considered when a kiln is built is the stacking of the bricks. Here once more the nature of the ground has to be considered. According to the greater or less difficulty of firing of the products, different methods will be employed. First the foot of the kiln has to be made. This foot consists of longitudinal channels arranged along the floor of the kiln to permit a draught to pass. The width of these channels is small enough to allow of their being covered by a brick placed lengthways;

VARIOUS KILN-FEET.

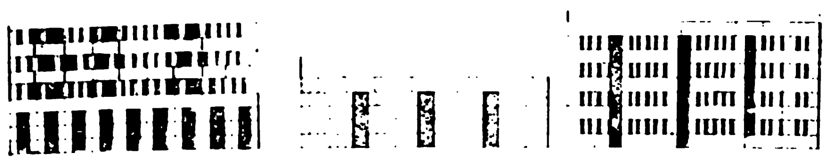


Fig. 220. Fig. 221. Fig. 222.

their height varies from 3 layers to 8, that is to say, from a foot to 2½ feet. If the kiln is small, and the goods easy of baking with a fairly moderate fire, we can adopt the arrangement in Fig. 220, which fails, however, if the products are difficult to bake on account of the waste it causes. In fact the foot supports the whole weight of the bricks stacked; if firing takes place at a high temperature, the contraction causes movements which make the whole mass unsteady, and all the bricks at the foot are deformed by crushing, while those of the fourth layer are opened in the middle by the weight they support. Under these conditions we must reduce the channels to the number absolutely necessary, say three, and they are arranged below the heating wells, as shown in Fig. 221.

The foot thus formed is of great resistance and does not give deformed products, but the bricks above the channel are always

a little curved or opened in the middle. In order to avoid this inconvenience, which, we repeat, is only excessive in the case of bricks requiring a high temperature for their firing, the width of the channel is diminished and its height increased (Fig. 222).

The foot of the kiln having been formed, the stacking is continued, and then arises the question of heating wells. The heating wells are hollows left between the bricks, below the holes in the arched roof, to receive the burning fuel. Their importance will be understood; with good heating wells a regular and economical firing is obtained; it becomes, on the contrary, bad and troublesome with badly arranged wells. Every brick-maker is said to have his own system of wells. We will mention a few. One (Fig. 220) is to be used with clays which fire easily; another is applicable to clays which bake with difficulty. The first requires open stacking, that is to say, the bricks are separated from one another by a distance equal to the thickness of a finger, the rows crossing at right or acute angles. The well is formed of interspaced bricks, placed one upon the other, and forming "chicane" (these bricks are distinguished in the figure by hatchings). The coal, falling from the hole in the arch, is scattered among these "chicanes"; a little remains on each brick and burns there, the bricks being at a sufficiently high temperature to cause its ignition.

A well-made well should retain the coal at different points of its height without letting a single piece fall on the floor of the kiln. These wells work satisfactorily provided the intervals between the bricks be neither too large nor too small. If too large, they allow the coal to fall into the channel at the bottom, where it accumulates and *burns* the foot of the kiln without baking the top; if too small, they are liable to be stopped up by an accumulation of fuel, and the effect is reversed: the top fires too much, while the bottom does not fire at all.

Finally, this kind of well does not give a sufficiently regular baking to products which are difficult of firing. We have found the kind of well represented on the right of Fig. 213 answer admirably.

The stacking is solid, that is to say, the bricks are close together

and placed in the direction of the length of the kiln. When we come below a row of holes, a hollow is left equal to half the length of a brick. This interval exists throughout the section of the kiln and constitutes the well, which is thus formed of the hollow between two "feuilles." It is evident that under these conditions the coal, finding nothing to restrain it, would fall on to the floor of the kiln. Therefore bricks are placed "en chicane" in this hollow in the following way: the first "feuille," which forms one of the walls of the well, is stacked perpendicularly without any projections; but in stacking the second, bricks are pushed forward here and there which approach the opposite "feuille" and interrupt the continuity. These projecting bricks will retain the coal. Generally they are placed in every other row of the height and at every third brick of the breadth, care being taken that the bricks so projecting are opposite to those of the lower row. The coal, meeting all these obstacles, is uniformly distributed throughout the mass of bricks, and produces a regular heat. In this solid stacking the draught of the channels at the foot would not suffice, and we must make a communication between the different wells so that the air may reach all the places where there is fuel, and cause it to burn. This is done by leaving in each "feuille," at every two or three layers, and at every other brick, small hollows in width about half or three-quarters the thickness of a brick. This hollow is covered over in the following row. As its width is small, the brick or bricks which cover it are not sufficient, especially as they are placed lengthwise. These little channels stretch in a straight line from one well to another, but of course it is not necessary that they should be in a line from one end of the kiln to the other; it is enough if they ensure connection between two neighbouring wells.

For this solid stacking, which gives fine products but which has the disadvantage of making the progress of the fire slower, open stacking is often substituted; the bricks are separated by a small interval, each layer or clamp crossing at a right or acute angle. The wells are made in the same way, and across the whole width of the kiln. It is not every clay which will bear this method of stacking; there are some which show the mark of the

space separating two bricks. However small this space may be it is said that the bricks are cut.

One important observation must be noted in building heating wells; this is that the fire always draws the bricks forward to about half the height, that is to say, that a "feuille" stacked perfectly vertical is found inclined when removed: as the upper part overhangs, it will even be necessary to take precautions in removing it. This movement always takes place in the direction of the draught. This being so, it will be understood that it is better to throw the axis of the well a little behind the axis of the heating holes, since the wells will come forward during firing. It even happens sometimes that, if in stacking, its axis is placed too far in front of that of the holes, when one comes to throw in the fuel the well is invisible, it has passed the holes. This accident is easily avoided: all that need be done is to throw through the fuel holes, into the interval between the "feuilles," a few pieces of brick, which will act as wedges and hold the "feuilles" in their places.

Transport of the Bricks from the Drying-sheds to the Kiln.—The most usual method is by wheelbarrows called technically "brouette à barque" (Fig. 201). They are made in wood and iron, and can carry fifty bricks each. When the drying-places are in storeys, lifts are used similar to those which we have described in speaking of the transport of bricks from the machine to the drying-sheds. The use of waggons necessitates a special installation, only possible with kilns of a certain size where space allows of some freedom of movement. The following is an arrangement which ensures an easy delivery, and avoids the use of turn-tables; the working of the latter is always slow, and has the inconvenience of injuring the goods through the shocks and jolts produced.

On each side of the kiln, and in the direction of its length, two trenches are dug, and in them is laid a railway to carry a transfer trolley (Fig. 182). This trolley carries a single, or preferably a double, line of rails of half-a-metre gauge placed perpendicular to the first. The half-metre rails correspond to other lines which join each door of the kiln to the transfer trolley.

These lines are fixed and continue into the kiln by means of movable branches which are laid in the direction of the place of stacking and afterwards removed.

The working is simple: the waggons, when they arrive from the outside drying-sheds, or are lowered by a lift from the upper storeys, are placed on the trolley, the rails of which have been put in line with those serving the drying-places; the trolley is pushed in front of the line corresponding to the compartment to be filled, and fixed by means of a bolt, then the waggon full of bricks is passed into the kiln. Near the door there is a curved branch leading to a line which ends with a turn-table. When the waggon reaches this turn-table it is turned round so that the brick-stacker may more conveniently take the bricks from it. Meanwhile the

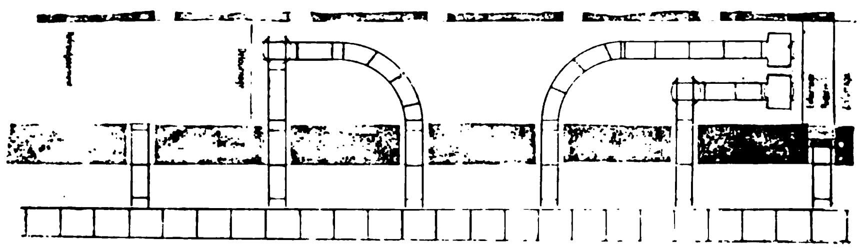


Fig. 223.– Installation for Charging and Discharging.

waggon-man has pushed out the empty waggon which was on the other turn-table, and which now goes on to the trolley in place of the one just sent inside. The trolley is unbolted, and it is taken to fetch another waggon which a second workman has loaded. A skilful stacker can fill a compartment containing from 12,000 to 15,000 bricks in ten hours. Everything is brought to him, the bricks and also the sand which is placed between the layers to prevent them from sticking together. While he is working, the waggon-men, who have time to spare, close the doors up with a wall 2⅓ inches thick, formed of bricks on edge and coated with clay. This wall is placed against the stacked bricks. Then a foot away they build another wall of bare bricks and of thickness equal to a brick's length; between they heap up clay (Fig. 212) to avoid any entrance of air which would interfere with the draught.

The good firing of the neighbouring bricks and the satisfactory progress of the fire depend upon the care with which a door is closed. From time to time the stoker looks round to see that no air is getting in by the doors; this would be shown by a whistling sound, and should it occur it is remedied by heaping clay up at the top of the door.

Registers.—We have seen that the closing up of the kiln at a particular point is effected by means of a register. These registers may be of paper or sheet-iron: they take the exact shape of the gallery. They are placed against the stacked bricks, and the chinks between the sides of the kiln and the register are stopped up with diluted clay in order to close it hermetically.

When the next compartment is full a second register is placed in position. This compartment is thus enclosed between two registers. But the first register is then removed and the draught is advanced one compartment.

Sheet-iron registers are in two parts which fit together by means of a groove plastered with clay. The lower piece is easily moved; the upper one, which is hemispherical in shape, is fitted with hooks; by means of chains passing through the heating holes it is hoisted above the first, and the whole is kept in position by a buttress which is taken away when stacking takes place. The removal of the registers is somewhat difficult on account of the lack of space. The upper part is held by chains, while the lower part is drawn out by means of a handle fixed to it; the upper part is then lowered and also taken out. For this removal, an opening of the thickness of the register is left in the thin wall against the bricks. The register must not be removed without first closing the door, for the draught would be stopped and the progress of the fire suspended.

These sheet-iron registers have several disadvantages: they are slow and difficult to move, they cause a loss of space, for the hooks project, and a space must be left for the descent of the upper part.

There are many advantages to be gained by substituting registers made of strong paper for the above. Yellow straw paper in rolls 1.4 metres high are used; this height, which is the

width of the paper, should be a little more than half the height of the gallery. The kiln is closed by cutting out a first rectangle of paper and placing it against the bricks; care is taken to open the trap of the compartment in order to cause draught and draw the paper against the brick. The second part of the register is made by cutting out a piece of paper in the shape of the arch; this is also placed against the brick. The edges of the paper are pasted with a little clay diluted very thin, and they are stuck against the walls of the kiln. The top is pasted with clay and the whole is thus completely attached.

When the register is to be destroyed, a long iron rod made red-hot in the fire is passed in by a heating hole and sets fire to it. The expense in paper is trifling and is made up for by the time saved in placing and removal of the sheet-iron registers, and also by economy in space, for the bricks of the next compartment are placed against the paper and help to keep it in position.

Fuel.—Any burning fuel serves for heating continuous kilns: such are wood, peat, and especially coal, which is generally used in the form of powder, called commercially "fine." This is very suitable for firing; being finely divided it spreads all round, burns quickly, and is cheapest. When the Hoffmann kilns were first introduced the economy was all the greater because this fine coal, which was not otherwise used, encumbered the mine-yards and was sold at a price very much less than that of ordinary coal. This difference in price, however, has much diminished since the installation in various commercial enterprises of furnaces capable of burning this slack.

Rich and poor coals are also very suitable for continuous kilns. Some prefer rich coals, on account of their long flame; others prefer poor coal, which heats more uniformly and without sudden outbursts.

Igniting of the Kiln—Method of Heating.—The ignition of the kiln is effected by heating one compartment by means of fire-bars placed in front of it; then when the bricks are red-hot, the heating is continued by throwing coal through the holes in the vault. In some kilns the igniting furnaces are placed permanently at one end of the kiln with their doors outside. When a

sufficient quantity of brick has become red-hot, and the fire has started properly, the furnaces are extinguished and their openings stopped up by a wall.

In preference to these fixed furnaces we recommend movable ones, which are installed in the kiln, and removed as soon as the fire is started. The construction of these furnaces is very simple.

Three of them are usually arranged in the width of the kiln; their bars are of cast-iron and the doors are formed of sheet-iron plates placed in front.

The length of the latter is determined by the length of the bars. In front of the furnaces a wall of bricks bound together with clay is built so as to completely close in the kiln; in this wall three openings are left for passing the gas to the furnaces. This wall almost touches the green bricks with which three or four compartments are filled. The bricks are thus enclosed between the wall of the furnaces, and the register placed against the last compartment. The whole forms an ordinary flame kiln, the draught passing through the vertical conduits and the central channel. We begin by heating with the "petit feu," then we pass to the "grand feu." The bricks in the first compartment are thus raised to a red-heat at the end of a few days; from time to time we make sure that the heat is sufficient to ignite the coal which is thrown in through the holes in the roof. When the coal burns well, we begin to heat from above while keeping up the fire in the furnaces. At last, when a compartment, or better still a compartment and a half, is raised to a red-heat, we let the fire in the furnaces go out, and heat only by the holes in the vault. To bring coal to the kiln, a small Decauville railway of .4 metre gauge is laid on each side; thus the fuel placed in a waggon is within reach of the stoker, who pushes the waggon forward as the fire advances. He takes the coal up in a round shovel like those in household use, and, raising the lid of the holes with a movable hook or with a handle fitted to the lid, he quickly throws the fuel into the well, *allowing as little cold air as possible to enter.* He goes in this way from hole to hole, beginning at one end of the compartment and finishing at the other; generally only one compartment

is heated at a time. When he has finished his round, he waits a certain time and then begins again in the same order. In order to measure precisely the interval between two heatings, a special clock is placed on the kiln which strikes once at the hour, two strokes at five minutes past, three strokes at the quarter past for beginning again, one stroke at twenty minutes past, and so on. In this way it is easy for the stoker to notice the time which has passed, especially at night. The heating times are generally ten minutes or five minutes apart.

The progress of the fire depends upon the degree of difficulty of baking of the products; an advance of from 4 to 8 metres a day may be expected, that is to say, from one to two compartments. If we take the first estimate, the stoker will, at the end of six hours' heating, begin to put fuel into another row of holes, and will leave one row behind him. As there are four rows of holes to each compartment, it follows that this operation will be repeated four times in the twenty-four hours. In order to remember at what time he began to heat a new row, he writes it down with chalk on the lids. When one row is no longer being heated, the well is closed with two bricks laid flat, and coal is placed on these two bricks for five or six hours. This coal does not fall down, it helps to maintain the heat under the vault; for the fire has always a tendency to descend, owing to the draught passing to the floor of the kiln.

A good precaution in firing is to measure the contraction in height of the mass of bricks with a graduated iron rod, taking the distance from the edge of the cast-iron shoulder at the end of the heating hole.

The draught is regulated by raising or lowering the trap-doors, the threaded rods of which are worked by a small flywheel (Fig. 213). The draught exists throughout the "enfumage," the "petit feu," and the "grand feu," but the holes behind the "grand feu" should have a return current. Draught and return current are easily distinguished from one another. When a lid is raised, there is immediate aspiration through the open hole if there is a draught, whereas if there is a return current the hot air is felt issuing from the hole. The stoker regulates his trap accordingly; there are

generally one or two traps open, sometimes three, according to the number of compartments in front of the "grand feu."

The draught should come from as great a distance as possible, that is to say, there should be the greatest number of full compartments before the one "en grand feu," so that as little heat as possible may be sent into the chimney.

The greater the distance of the draught is, the more regularly does the fire progress; the obliquity of the path of the gases going from the outer wall of the kiln to the central channel is less great; it rarely, however, advances more quickly towards the central channel than towards the outside wall. It is almost always necessary to keep the fire in this part several holes behind.

Progress of the Fire.—Firing and "enfumage" take place in an oxidising atmosphere. The air in fact reaches the firing compartment after having been heated but not having lost its oxygen; consequently the products just baked, and those being baked, are in a very oxidising atmosphere. As the air is in excess, combustion does not absorb all the oxygen, and the compartments in front of the "grand feu" are also in an oxidising atmosphere, but less so than that in the compartment preceding the "grand feu."

In the Hoffmann kiln, then, it is immediately after firing that the products are exposed to the most oxidising gases, while in intermittent kilns the gases are oxidising before firing and somewhat reducing during and after. Attempts have been made to render the continuous kiln reducing and oxidising at will by lowering the draught to its minimum, and stopping it completely for half an hour three or four times in the twenty-four hours. The results are not very satisfactory, and are costly on account of the delay caused in the progress of the fire.

Enfumage.—As we have already stated, the object of this process is the removal of the water contained in green products before they are subjected to a high temperature. In continuous kilns the "enfumage" is effected by the hot gases coming from the compartment "en grand feu"; as these gases progress towards the channel leading to the chimney, they cool and at the same time take up moisture produced by the combustion of the coal

and the complete desiccation of the products over which they pass. As long as these damp gases pass over bricks which are already heated to a high temperature there is no condensation, but we must avoid their reaching cold products like those in the compartment from which the register has just been removed, for the moisture will be deposited on them, and produce a damaging effect, giving the fired bricks an irregular colour, yellowish or whitish in places and disagreeable to the eye.

These accidents, however, are only persistent in *lightly fired products, they disappear under strong firing.*

Several means of obtaining a good "enfumage" have been recommended. In the Simon kiln two large cast-iron stoves are placed over the compartment and isolated between two registers; they are joined by a pipe to the heating holes. The trap of the compartment is slightly opened to make a moderate draught. Two stoves are placed near the outer wall and one in the middle of the row of holes farthest from the air trap; thus the hot gases pass over the greater part of the compartment. The progress of the "enfumage" is observed by raising the lids; as long as it is not complete damp soot will be observed on the cast-iron, and when this disappears the "enfumage" is completed. An average of twenty-four hours is required for one compartment.

Attempts have been made to carry out "enfumage" by means of the heat given out by the fired products when cooling, a heat which is far from being all absorbed by the air necessary for combustion. The arrangements consist of a series of air channels placed over the central channel and communicating with the heating holes. The orifices of these channels are closed by a valve or trap to each compartment. This kind of installation is very troublesome; it increases the dimensions of the kiln, and to a certain point diminishes its solidity. It is evident that the more hollows there are in the masonry of a kiln, the more is the resistance to the effects of dilatation decreased.

Moreover, some manufacturers contend that when hot air is borrowed from cooling products for the purposes of "enfumage," the progress of the fire is slackened, and the heat is greater in the discharging compartment.

M. Fillard, the well-known pottery expert, resolutely rejects "enfumage" by stoves or any other similar method. According to him, a separate "enfumage" is in opposition to the continuity of the kiln; he effects it completely by a properly managed draught. For instance, directly the register is set fire to, a new compartment is put into communication with the others, the trap of the compartment is *very slightly* raised, and the draught passes through the two or three preceding ones.

Thus the water-vapour does not condense on the cold products; the latter are slowly warmed by contact with the hot walls of the kiln and the very slight draught going to the last air hole. When no more deposit of water is observed in the neighbourhood of the burnt register (this is easily verified by passing a cold iron rod through a heating hole), the opening of the traps previously raised is reduced, and that of the last increased. By these precautions all accidents due to the deposit of water-vapour on cold products are avoided; we get rid of the trouble of removal and maintenance of the fire in the stoves, and we economise fuel.

The importance of only firing dry products is known to all potters; not only do they behave better under firing, but the cost of fuel is considerably diminished. In fact every kilogramme of water to be evaporated means 637 calories, that is to say, about 100 grammes of a coal giving 7000 to 8000 calories; for, besides the heat of vaporisation, we must take into account the heat necessary to raise water-vapour to 300° or 400° C., the temperature at which water of combination is given out.

If the bricks contain 2 or 3 per cent. of hygrometric water, as is generally the case, the expense of fuel on this head will be, for every 1000 kilos of green products:

$$1000 \times 2 \times 0.1 = 2 \text{ kilog. of coal.}$$

If the quantity of water is as much as 10 per cent., 10 kilos of coal will be required, representing 28 kilog. per 1000, if we take the weight of 1000 green bricks to be 2800 kilog. It is therefore highly advantageous to dry the products well.

COST OF FIRING IN CONTINUOUS KILNS.—In accordance with the remarks made on p. 224, the cost of fuel may be estimated at from 40 to 60 kilog. per 1000 kilog. of fired

products, the firing taking place at a temperature of from 1100° to 1200° C.

ESTIMATE OF A CONTINUOUS KILN.—The price varies according to the form of the kiln. In M. Bourry's opinion round kilns are preferable, as regards cost, for a daily production of from 3000 to 7000 bricks; for an output of 5000 to 10,000 there is very little difference between the two shapes; above that number, elongated kilns are more economical, and take up less room. For iron-plated kilns with sixteen compartments, like the one represented in Figs. 213 to 217, the following are the approximate dimensions:—

1. Outside measurement: Length, 34.8 m.; breadth, 7.5 m.; height, 2.75 m.
   Dimensions of one compartment: Length, 4 m.; breadth, 2 m.; height, 2 m.; cubic content, 12.6 cubic metres.

Rough masonry	224 cub. metres	400 cub. metres.
Brick ,, ...	176 ,,	

2. Outside measurements (Figs. 213 to 217): Length, 35.8 m.; breadth, 9.9 m.; height, 3.4 m.
   Dimensions of one compartment: Length, 4 m.; breadth, 3 m.; height, 2.7 m.; cubic content, 28.7 cubic metres.
   Rough and brick masonry . . . . 600 cub. metres.

It will be seen from these figures that the volume of the masonry is far from being proportional to the cubic content.

We shall now give the detailed estimate of the above kiln, adopting, for the sake of uniformity, the same prices as before:

Masonry	600 cub. m. at 30 fr. =	18,000 fr.
Sand or clay for filling the hollows of the masonry	200 cub. m. at 1 fr. 50 =	300
Iron-work: 40 double iron plates bound by 20 iron tie-rods (.03 m.) with double nut . . .	6700 k.	
224 cast-iron lids and shoulders for the coal holes .	3000	
16 traps used as registers with shoulders and raising gear	2000	
3 cast-iron openings with double sheet-iron plate for the central channel	300	
	12,000 k. at 30 fr. =	3,600
Sundries		100
		22,000 fr.
To this sum must be added for the chimney		5,000
The kiln works without being covered, but it is better to shelter it. A simple wooden shed covered with tiles, 40 m. long and 20 m. broad, costs about		8,000
Cost of kiln with chimney and building		35,000 fr.

If storeyed drying-rooms are required, the price is increased.

A kiln constructed as above is very solid, elegant, and does not take up much room. A certain economy is effected by omitting the iron plating, and increasing the thickness of the walls. This is cheaply done by supporting the inside brick facing with buttresses between which clay is heaped up; the whole is covered with a facing of flint or rubble masonry.

B. CONTINUOUS KILNS WITH GAS FUEL.—*Historical and General Remarks.*—The advantages gained by firing pottery by the combustion of gases were pointed out long ago by Ebelmen and Salvetat, who had specially in view porcelain and faïence. It was only much later, in 1869, that eminent manufacturers like Muller, Marle, etc., undertook to apply gas firing to architectural pottery, and especially to bricks. If the question seems, theoretically speaking, simple, and is presented in a seductive manner, it meets nevertheless in practice many difficulties which have much hindered its success. It was in fact necessary to find a kiln which would present evident superiority over the Hoffmann kiln, and which would effect firing as economically, even more economically if that were possible.

The few small disadvantages of the Hoffmann kiln are as follows:—

The presence of ashes, the residue of combustion, which the draught carries into the different parts of the kiln, and which may become attached to the products;

The direct contact of the fuel with the bricks of the well, which always causes loss;

The cooling caused by the entrance of cold air when the solid fuel is thrown in; for however short a time the lid may be opened, as the action is frequently repeated there is a sensible loss of heat;

The difficulty of easily transforming the oxidising action of the kiln, which is the usual action of the Hoffmann kiln, into the reducing action sometimes necessary for certain products;

The impossibility of getting a constant heat throughout the kiln, and the difficulty of attaining very high temperatures.

The use of gas kilns does away with all these inconveniences,

at the price of some difficulties, however, the most serious of which has been, until very lately, an increase of the expense of firing. That can easily be understood. The problem before us as to the firing of bricks is as follows: how to raise to a high degree of temperature products which we should be able to introduce and withdraw in a continuous manner. If it is admitted that these products should be fixed with respect to the fire which itself moves, we come inevitably to this conclusion: collect the gases made by the gas generator so as to distribute them afterwards to the place of combustion. But, in order that a gas generator may give its maximum of effect, the gases must be used as hot as possible, at 400° or 500° C., their temperature when issuing from the generator.

In the present case this is impossible; they have to pass through the whole length of the kiln, hence there is a cooling which causes a certain loss of heat, and the condensation of the soots and tars carried off by the gas.

This tar at last obstructs the channels; we get rid of it by burning it in the conduit itself by letting in the air, communication with the generators being interrupted, and thus a stoppage of a few hours being caused in the working of the kiln. Besides, this short stop only takes place every five or six months with a well-managed generator, and may even be altogether avoided.

As for the cooling, it is reduced to a minimum by placing the gas generators at the end of the kiln. The real cause which has so long delayed the application of gas kilns to the firing of bricks is that the more a machine is perfected, the more does its management become delicate and require care and precautions.

The Hoffmann kiln was an advance on intermittent kilns; some time was required to achieve its triumph, and even to-day it is certain that many manufacturers do not profit by all the economy which it may bring, because the possession of a machine is not everything, much lies in its proper handling. Gas kilns are an important advance on the Hoffmann kiln; for that very reason they require more skill in management, and above all a change of habits in the workmen, which is not always easy to obtain. When one thinks of the details on which the success of

a commercial operation so often depends, one perfectly understands the difficulties which hinder those who are urging the firing of bricks by gas.

In our opinion, then, the objections made to gas kilns—such as danger of explosions, greater cost of construction, obstruction of conduits by tar, more expensive firing, etc.—have very little, if any, foundation. But we repeat that to succeed in using them carefully, well-trained workmen are required who are capable of *ensuring a steady and uniform working of the generator*; there lies the whole secret of success.

Gas Generator.—We know that when a layer of fuel, not more than 6 or 8 inches thick, is burnt on a gridiron, the air passing across this incandescent layer burns it completely, turning it into carbonic acid by means of the oxygen contained in it, so that the products of combustion consist mainly of nitrogen and carbonic acid, and, in smaller quantities, of water-vapour, oxygen, etc. All these gases are inert.

If the thickness of the fuel be increased, and the quantity of air assisting combustion be reduced, the result is different. The carbonic acid formed in the lower strata of the coal is reduced while passing through the red-hot upper part, and gives up oxygen; an extremely inflammable gas is thus formed: carbonic oxide. This is the reaction which takes place in high furnaces. At the same time, small quantities of hydrogen and carburet of hydrogen, also inflammable, are produced. The gases given out by this slow combustion of the coal consist especially of nitrogen and carbonic oxide, and, in smaller quantities, of hydrogen, carburets, water-vapour, etc.; this mixture has received the name of *generator gas.*

Another more economical gas called *water gas* is produced as follows. The water is formed by the combination of oxygen and hydrogen; at a very high temperature, about 1000° C., this combination is destroyed, and the two elements separated. This reaction takes place more especially when water is thrown on an incandescent furnace; the oxygen burns the coal, and the hydrogen is set free. If the operation takes place in presence of an excess of coal, the carbonic acid produced will be reduced to carbonic oxide; the gases of combustion will contain

carbonic oxide and hydrogen, both inflammable gases, and, in small quantities, carbonic acid and nitrogen. This result is obtained in practice by passing a current of water-vapour over the incandescent grate of a generator. The decomposition takes place, but as it is endothermic, that is to say, that it absorbs heat, the coal gets cooler, and the reaction would cease if the entrance of vapour were not stopped to give place to an injection of air. During this second period generator gas is produced. When combustion has recommenced the air is stopped and vapour admitted, and the process continues. The duration of these alternate reactions varies according to the conditions of the installation; for instance, water gas will be made for four minutes, and then for eleven minutes heat will be raised again and generator gas produced.

Water gas has a much greater calorific power than generator gas, as their average compositions show—

	Composition of 1 cubic metre.		Combustion value in calories.	
	Generator gas.	Water gas.	Generator gas.	Water gas.
Carbonic oxide	237	440	723	1342
Carburets of hydrogen	19	4	162	34
Hydrogen	65	486	168	1254
Nitrogen	639	37	0	0
Carbonic acid	40	33	0	0
	1000	1000	1053	2630

One kilog. of coal, the heating power of which is about 8000 calories, gives from 4.5 to 4.9 cubic metres of generator gas, which, when cooled to 20° C., has as calorific value: $\frac{4.5 \times 1053 + 4.9 \times 1053}{2} = 4949$ calories, that is to say only 62 *per cent.* of the calorific value of the coal used in its preparation.

In water gas we recover 80 *to* 85 *per cent.* of the heating power of the fuel, half in the form of generator gas, and half in the form of water gas.

The preceding figures are the result of experiments made in the Krupp factories at Essen.

It is advantageous, then, to use water gas for the firing of bricks, as these cheap products require as low a cost of production as possible. The apparatus for the production of gas is the same in both cases, and so is the kiln, as we shall see below.

As in the case of kilns with solid fuel, there are a certain number of gas kilns recommended by different makers (Schwandorf, Marle, Simon, etc.), which only differ from one another in details.

Fillard and Gastelier Kiln.—This kiln was invented and constructed by M. Fillard (successor of M. Gastelier at Fresnes), one of the most ardent defenders of gas firing, who has succeeded, after persevering attention, in devising a really practical form of kiln.

This rectangular kiln does not differ in its main features from the kiln which we have described in detail, except as to its central portion. The smoke channel has above it another, stretching the whole length of the kiln and serving for distribution of the gas. The arched roofs are pierced, as in ordinary continuous kilns, with a series of heating holes closed by movable lids. The channel conducting the gas has also in its upper part orifices corresponding to each row of holes; these orifices are also closed by movable lids. The combustion of the gas takes place in hollow pipes, called "chandelles," made of refractory clay, and pierced with holes. These pipes, which are formed of several parts fitting one within the other, are movable and placed below the stoke holes. They are put into communication with the gas channel, when necessary, by means of a pipe with several branches which are fitted to the opening of the channel and the corresponding stoke holes; these branch tubes are fitted with valves which permit of the communication between the "chandelles" and the gas conduit being shut off.

As for the gas generator, Figs. 225 to 227 show its construction: it has two furnaces working simultaneously. The gases pass into a chamber which acts as a gasometer, and afterwards enter the central conduit of the kiln.

The generators may be placed anywhere; most generally they are at the end of the kiln (Figs. 228, 229), but if space does not allow of this, they may be put at the side of the kiln. Water is always kept beneath the fire-bars; this water evaporates, and in passing through the incandescent mass gives out water gas.

GAS GENERATOR. (Scale of 11 millimetres to the metre.)

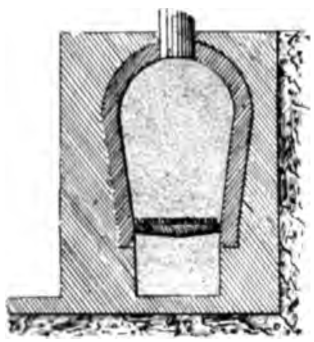


Fig. 225.—Transverse Section of a Furnace.

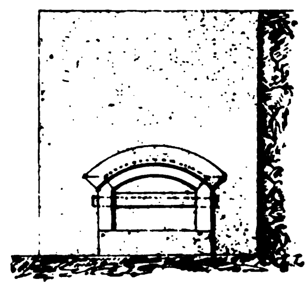


Fig. 226.—Elevation of a Furnace.

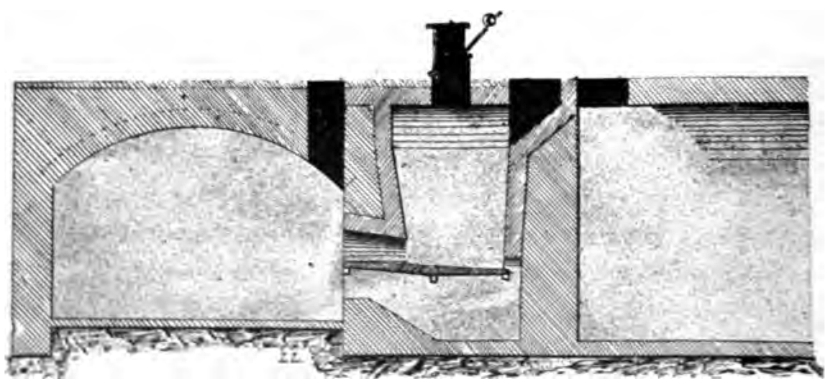


Fig. 227.—Longitudinal Section of a Furnace.

Working of the Kiln.—The stacking is done as in other continuous kilns, but heating wells are not used. When we come to a row of holes, we place the "chandelles" underneath, the joints are luted with clay, and the stacking is continued, the space between two "chandelles" being left free, so that there is throughout the section of the kiln an empty

space of the thickness of the "chandelles"; it is in this space that the combustion of the gas will take place.

The igniting of the kiln offers no special feature, except that the gas generator should work when a sufficient quantity of brick is raised to a red-heat capable of setting fire to the gas. The distribution of the latter is effected by the sheet-iron conduits of which we have spoken, and which are placed over the kiln. The number of rows of "chandelles" lighted, depends upon the degree of firing and the nature of the products to be

GAS KILN WITH GENERATOR. (Scale of 5 millimetres to the metre.)

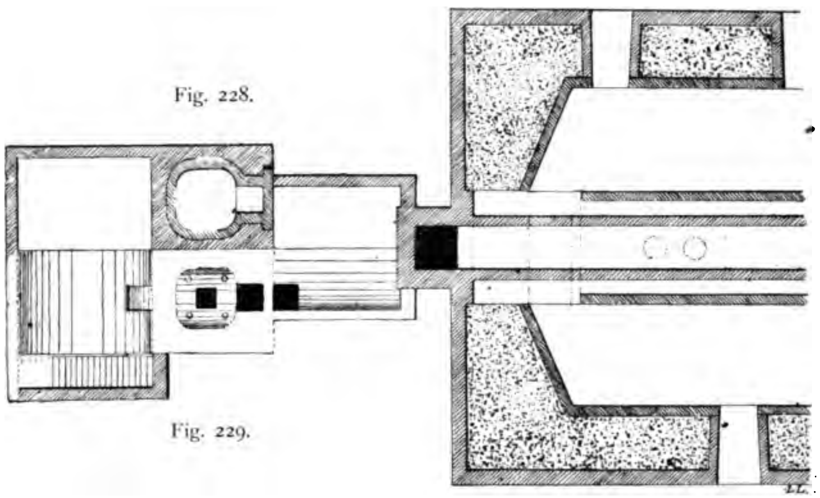


Fig. 228.—Horizontal Section.
Fig. 229.—Horizontal Section of the Kiln, and View of a Generator from Above.

baked; this number generally varies from two to six. The supply of gas is regulated by stop-cocks placed in the movable conduit above the "chandelles." It is better not to introduce the gas into the compartments until the bricks contained in them have almost reached the proper degree of firing. In this way the gas which is not burnt in the first layer will be burnt in the others, and no useful part of the fuel will escape into the chimney. The progress and height of the fire in the kiln is observed through little openings in the roof.

The action of a gas kiln is the same as that of one with

solid fuel. The air enters through the doors of the cooling compartments, passes over the fired products, drawing heat from them, and comes in a very hot state into contact with the "chandelles" which are emitting gas. The latter burns with a brilliant flame behind the fire where the air is in excess, but the flames are duller and longer in front where the air contains less oxygen. The firing thus takes place in an oxidising atmosphere; moreover, this is the method to be preferred in most cases; but if it is necessary, the atmosphere of the kiln may in a few moments be made a reducing one by diminishing the draught and increasing the volume of gas introduced. In order to avoid the loss of the excess of gas, which would escape by the chimney, this excess is burnt by introducing a little air in front of the fire. There is no disadvantage in the fact that the atmosphere at that point is an oxidising one, as the "enfumage" of all pottery takes place in the midst of excess of air.

The gas being easily distributed, it may be seen that it is possible to stimulate the fire at a given point by opening wide the stop-cocks regulating the entrance of gas into the "chandelles"; in the same way it may be moderated by lowering these valves and even extinguishing one or two "chandelles" by closing them entirely.

The temperature which can be attained in a gas kiln is very high, and stoneware pastes fire well in them; these pastes may even be melted by stimulating the fire to its greatest power, which, however, can hardly be considered as a normal state.

Continuous Gas Kiln with Multiple Firing Chambers.—We shall describe one type of this kiln used by MM. Schneider et Cie. in their refractory product works at Perreuil, near Creusot. It is shown in Figs. 230, 231, 232.

The kiln has an outside diameter of 20 metres and possesses fourteen compartments, each measuring: depth, 2.9 m.; mean breadth, 2.5 m.; height, 2.6 m.; this corresponds to a cubic content of about 19 cubic metres. They are separated by walls (Fig. 232) pierced with three openings making communication between them (Fig. 230). The gas arrives below the floor and penetrates

into the firing compartment by three vertical openings placed below those connecting the compartments with one another.

In stacking, an empty space is kept between the separating

CIRCULAR CONTINUOUS GAS AND HOT-AIR KILN BY SCHNEIDER ET CIE.
(Scale of 3.1 millimetres to the metre.)

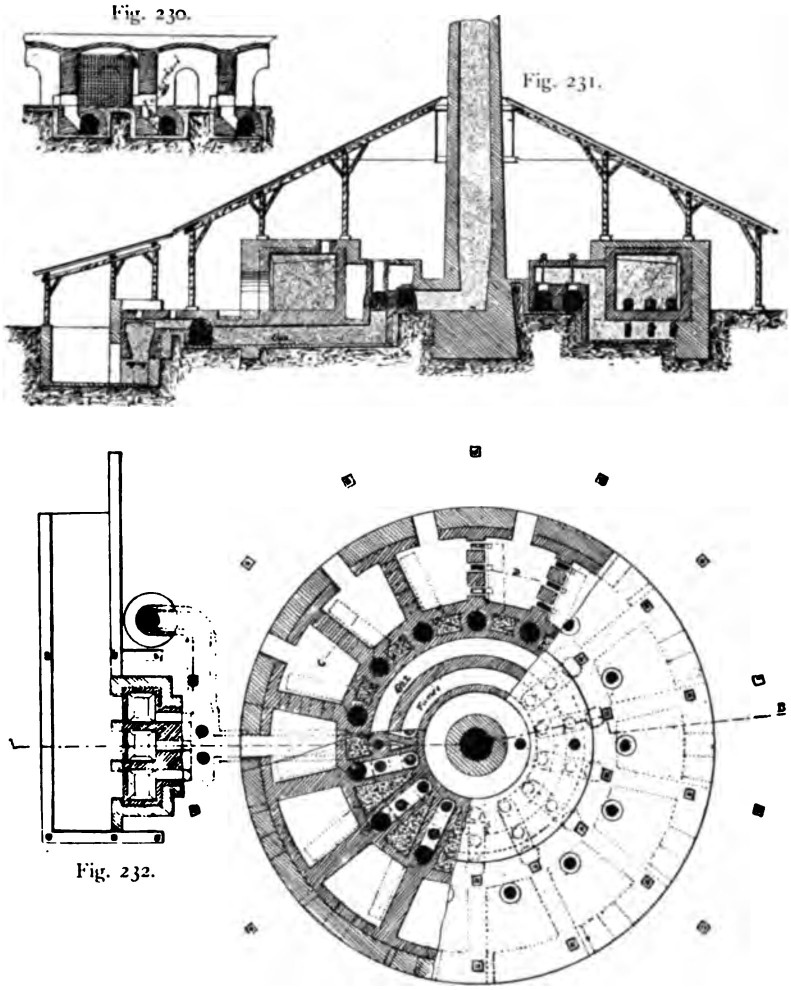


Fig. 230.—Section C D. Fig. 231.—Section A B.
Fig. 232.—Horizontal Section of the Kiln and Generators.

wall and the products (Fig. 230); it is in this chamber that combustion is begun, by the mixture of the gas and the air which has been heated in passing over the cooling fired products.

The combustion when once begun spreads itself through the channels left in the stacks, the hot gases continue their way, heating the products stacked in the following compartments, and finally reach the chimney, 30 metres high, placed in the centre.

The gas generator has 3 gridirons, 1 metre by 1.3 metres. The temperature of this kiln rises to 1500° C.; hence the inside is built of refractory bricks. The firing of a compartment requires from 12 to 16 hours according to the nature of the stacked refractory products, and its cooling requires 3 to 4 days.

Water-gas Kiln.—In this kiln we have again the parallel

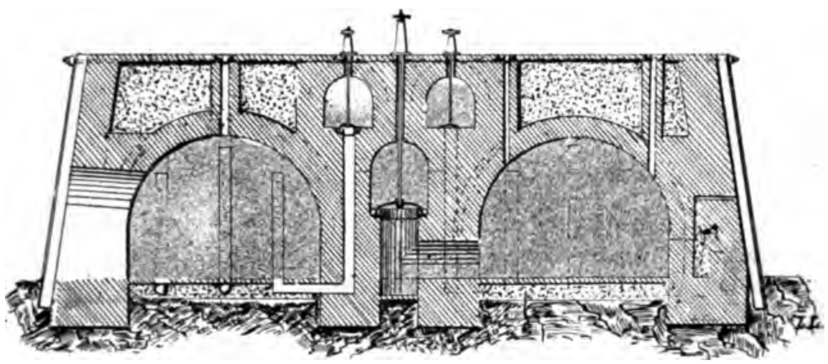


Fig. 233.—Continuous Water-gas Kiln—Transverse Section. (Scale of 8.3 millimetres to the metre.)

galleries of the rectangular continuous kilns. The distribution of gas is effected by two parallel galleries placed in the centre; the gas passes through vertical conduits under the flooring of the kiln and issues by "chandelles" placed below the orifices of the conduits. This was the arrangement of the first gas kilns; it had to be abandoned in favour of a distribution of gas from the roof on account of obstruction of the conduits by tar. This obstruction need not be feared with purified water gas.

Each conduit is closed by a valve which is worked from outside; in the kiln shown (Fig. 233), there are three conduits placed side by side and corresponding to each row of "chan-

delles." The conduits are made simply of earthenware pipes encased in masonry. The stacking and the management of the fire are precisely the same as in a generator-gas kiln.

COST OF A GAS KILN. — *Fillard System.* — We shall make this estimate for a kiln capable of firing from 5 to 6 million bricks annually and having as dimensions: length, 49 metres; breadth, 11.35 m.; and height, 10.55 m. The chimney is 35 metres high and has a diameter at the summit of 1.40 m.

Brick masonry for interior	270 cub. m.	
Rubble or mill-grit for exterior	525	
Total	795 cub. m. at 30 fr. =	23,850 fr.
Cast-iron for generator and kiln	9000 k. at 30 fr. =	2,700
Sheet-iron and accessories		900
"Chandelles" of refractory clay and sundries		1,550
		29,000 fr.
We must add for the chimney		5,000
,, ,, ,, building		8,000
		42,000 fr.

Schneider System.—The estimate of a kiln like that in Figs. 230 to 232 is thus calculated—

Concrete of crushed stones and hydraulic mortar	135 cubic metres	Total: 1167 cubic metres at an average price of 30 fr. per cubic metre = 35,010 fr.
Stoneware and brick masonry	540 ,, ,,	
Brick masonry for chimneys	82 ,, ,,	
Refractory brick masonry	410 ,, ,,	
Iron, cast-iron, steel, and sheet-iron; 26,050 kilog. at an average price of 30 fr. per 100 kilog.		= 7,815
Building (42 cub. m. of timber and 663 sq. m. of roofing), about		7,175
		Total = 50,000 fr.

These figures are only intended as a rough indication; they may increase or diminish, according to the cost of labour and materials in the district where the kiln is built.

COST OF FIRING IN GAS KILNS.—For the same reasons as we have already stated, it is difficult to fix this cost exactly for want of exact experiments which are capable of comparison. It is certain, however, that with a well-managed kiln, the cost is

no greater than with a solid-fuel continuous kiln; M. Fillard states that, in his factory at Fresnes, he has reached a lower cost. He estimates the consumption at 50 *kilog. of ordinary coal* per 1000 kilog. of fired products.

In the Schneider kiln baking refractory products at 1500° C., the consumption is as much as 110–115 *kilog. of coal* per 1000 kilog. of products.

But the manifest superiority of gas firing consists in the beauty and quality of the results obtained, advantages which are much appreciated for delicate articles such as facing bricks, tiles, squares, etc.

Temperature of Firing of Bricks—Its Measurement.—Nothing is more variable, naturally, than the temperature at which the firing takes place, considering the variety in the composition of the clays used. This temperature usually oscillates between 1000° and 1200° C., but it may rise to 1300° or 1400° C.

In practice there is no advantage in measuring it; the degree of firing is observed by noting the contraction, as pointed out on p. 226.

But if we wish to find out at what temperature the firing is taking place, we must have recourse to the pyrometric indicators. These are mixtures, in variable proportions, of different oxides which soften at different temperatures. They have been specially studied by the German pottery expert, Seger. To make use of these instruments, which are in the shape of a four-sided pyramid, a series of them is placed in the kiln, and when the proper degree of firing is reached, their condition is examined. The number is noted of the one whose point has begun to bend, the next one being still intact. In order to regulate later firings, it will be sufficient to place in the kiln several indicators near on the list to the one noted, and to observe their behaviour.

Indicators can be obtained in the trade (in Paris, from MM. Poulenc frères) fusible at intervals of 30°.

The fusion of metals and even the colour of the fire only will show the temperature reigning in a kiln.

Here are some hints on the subject—

Aluminium melts at	625° C.	Dark red.
Zinc volatises at	930° C.	Cherry colour.
Silver melts at	954° C.	Light cherry colour.
Gold melts at	1045° C.	Orange.
Copper melts at	1054° C.	Orange.
White cast-iron melts at	1130° C.	Light orange.
Grey melts at	1220° C.	White.
Nickel melts at	1410° C.	Brazing white.
Palladium melts at	1500° C.	Dazzling white.
Platinum melts at	1775° C.	

A large number of types of *pyrometer*, based on different systems, are in existence, but are seldom used in pottery. The simplest one, Wedgwood's, gives very inaccurate indications; the best one, the thermo-electric pyrometer of M. Le Chatelier, is too delicate for practical use.

Production of Kilns Relatively to the Heat Used.—The production of a kiln, from this point of view, is given by the relation between the number c of calories theoretically necessary for firing products at a stated temperature, and the number C of calories produced by the combustion of the coal employed.

To determine the ratio $\frac{c}{C}$ we must find e from the composition of the paste and the temperature T at which it is fired.

The factors of this calculation are—

1. The heat necessary to evaporate the weight e of the hygrometric water;

2. The heat absorbed by the departure of the weight E of the water of combination;

3. The heat available for raising 1 k. of clay from the ordinary temperature to T°, supposing .2 to be the specific heat of the clay, between 15° and 1400° C., which is a sufficiently near approximation.

It is supposed that the quantities of heat given out or absorbed by the chemical transformation of the silicates balance one another, and that the absorption of heat due to the decomposition of the carbonates, when there are any, may be neglected.

The number of calories theoretically necessary to fire a given weight of clay being thus calculated, we must add to this

number that due to losses of heat, the principal of which are: (1) loss due to the heating of the inner walls of the kiln; (2) loss due to the radiation of the outer walls; (3) loss due to the hot gases passing through the channels to the chimney; (4) in gas heating, loss due to gasification.

All these losses are very difficult to estimate in practice, therefore it is much simpler to weigh the quantity of coal employed in firing a given weight of the products, and determine the calorific power of this coal. Thus we have the number of calories practically necessary for the firing. Comparing the number so found with the number theoretically necessary, we shall have the loss of heat due to the various causes enumerated above, and consequently the thermic production of the kiln.

This production is far from being constant; it depends, above all, upon the good management of the fire and the stacking, two important factors in the firing of pottery.

§ 2. DIMENSIONS, FORMS, COLOURS, ORNAMENTATIONS, AND QUALITIES OF BRICKS—HOLLOW BRICKS.

Bricks have always the shape of parallelopipeds of three unequal dimensions bearing a certain relation to one another. Ancient bricks were larger than those of the present day and their dimensions did not bear the same relation to one another. At the present time the width is generally about half the length, and the thickness about half the width.

The latter dimension should not exceed .12 m., so that one may take up in the hand a brick laid flat; the thickness does not exceed .07 m. on account of drying, which would be too slow, and scarcely ever is less than .05 m., except in special cases.

The object of the relation between the length and breadth of bricks is to facilitate dressing. Brick walls, in fact, are divided into partitions, the thickness of which varies from that of one brick laid on edge or flat in the direction of the width or length, the junction being crossed, and walls of one or several bricks' breadth: a brick and a half, two bricks and a half, etc.

These methods of dressing make the work easier and increase the solidity of the masonry; they can only give good results with a brick of very regular shape, especially as regards thickness, for the layers must be of the same height.

The table below gives the dimensions of the principal types employed in different countries.

The dimensions given are those most generally found, but special bricks are manufactured for special uses. For example, some have only half the usual length, and are: .11 × .11 × .06; they are used for making joints without having to cut a brick in two; others have only half the usual thickness (.22 ×

Name of Country.		Dimensions in Centimetres.				Price per 1000.	Remarks.
		Length.	Breadth.	Thickness.	Cubic Content.		
France	Marseilles brick	21.5	10.5	5-7	1210-1694	(1)	In Paris, the bricks of .055 are reserved for façades, and the thicker ones for interiors. In certain buildings, briquettes of less than .05 thickness are used. Clinkers are used for paving yards and stables. The cubic content of the mortar used in brick masonry varies from 10 to 20 per cent. of the total volume, according to the care used in making the joints.
	Burgundy ,,	22	11	5.5	1331		
	Paris ,,	22	11	6-7	1452-1694		
	Type Union Céramique	22	10.5	5.5	1270		
	,, Northern Architects	22	10.5	6	1386		
	,, Clinkers	16	6	4	384		
Germany	,, Normal	25	12	6.5	1950		
England	,, Minimum	23.6	11.5	7.6	2040		
	,, Maximum	25.4	12.4	7.6	2390		
Austria	,, Normal	25	12	6.5	1950		
Belgium	,, *Kleynestern*	3.5	5	3.5	61		
	,, *Derdeling*	15	7.3	3.8	416		
	,, *Papesteen*	18	8.5	4.5	688		
	,, *Klampstein*	19	9	4.7	761		
	,, Gand	22	11	6	1452		
Holland		26	12	5.4	1684		
Switzerland, Normal type		25	12	6.5	1950		
United States		19.5	9.8	5	980		

(1) Below are some catalogue prices; they are capable of reduction, and are for goods taken at the factory.

		Weight.	Price.
Burgundy	Montchanin	2.7 k.	60 fr. stamped.
	Perrusson	2.6 k.	65 fr. ,,
Champagne	Gilardoni frères	2.5 k.	35 fr. hand-made. 40 fr. die-made.
Normandy	Argences	1.9 k.	48 fr. ordinary. 55 fr. stamped.
	Rouen (no reduction)	2.5 k.	21 fr. hand-made. 28 fr. stamped.
Paris	Brault	2.6 k.	55 fr. stamped.
	Muller	2.5 k.	50 fr. ,,
	Radot	2.6 k.	60 fr ,,

$.11 \times .03$), and are used for cellar partitions or to make up a difference of level; and finally, the bricks called "closoirs," $.22 \times .055 \times .055$, have only half the breadth of ordinary bricks. When the bricks are less than .055 m. thick they are called "briquettes." Briquettes exist of 2, 3, 4, and 5 centimetres in thickness. The brick-maker may of course manufacture any brick which lightens labour, and builders often find it advantageous to use it, even when more expensive, to avoid the always burdensome expense of cutting, and to improve the workmanship.

Shapes.—Ordinary bricks, as we have stated, are in the form of parallelopipeds with the dimensions above shown, but for special purposes bricks of special shapes are made, and the principal examples of these are shown in Figs. 234 to 257.

The ordinary shape (Fig. 234) is naturally the one most generally used. Conical bricks called "coin" (Fig. 235) are used for arches whose surface is solely formed of ends; for those into which only sides enter, bricks called "couteau" are taken (Fig. 236).

For the beginning of arches the bricks have only one inclined face. This inclination of the faces bears a relation to the radius of the arch.

The outside embrasures of doors and even of windows are made with bricks one edge of which is more or less rounded (Figs. 239, 254).

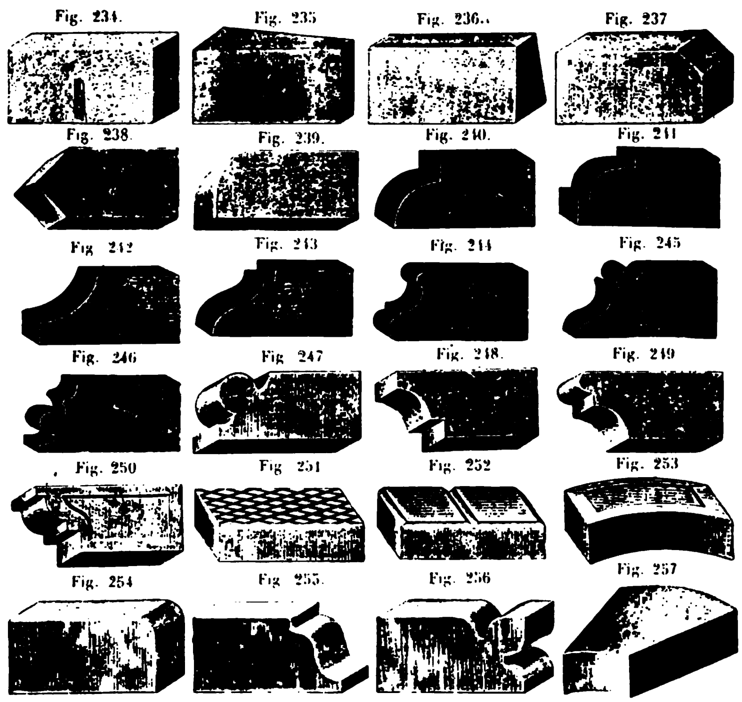
For entrance pillars, or to decorate the coping of a wall, bricks are used having one (Fig. 237) or two corners (Fig. 238) cut.

Bricks with moulded profiles (Figs. 240 to 250) are used in coping enclosure walls, in house cornices, garden borders, etc.

The masonary of wells or fully arched vaults requires to be economical and well made, bricks of the arched shape shown in Fig. 253.

For large factory chimneys, bricks are used of the shape of that in Fig. 257. Finally, paving bricks have hollows or ribs on their surface to prevent slipping in walking on them (Figs. 251, 252).

The manufacture of these bricks is performed in the same way as that of ordinary bricks, the dies having the shape required; the bricks are most frequently stamped with presses whose moulds are of the desired size and shape. Each kind of brick therefore requires a special die and mould which can only be used for that class of brick. If, then, the manufacturer has a certain number of types, he must have a considerable stock of apparatus which is only used to make annually a limited number



Figs. 234 to 257.—Bricks of Various Shapes.

of bricks. The amortisation, interest, and maintenance of this stock will raise the cost of these special bricks all the more, as the consumption of them is small.

Colours.—The colour, which is very diverse according to the nature of the clays, varies from yellowish white through yellow, yellowish red, bright red, violet, and grey, to dark brown. For bricks intended for façades the colour should be uniform over the whole surface. This condition is not necessary for inside

masonry, but bricks of a good make usually present a single tint; those which are variegated are made of insufficiently prepared material or contain many impurities. In fact, the foreign substances enter during firing into combination with the clay, and, if the paste is not very homogeneous, produce various discolorations.

The gases of combustion also have an effect on the colour of bricks; this colour will be different according as the gases are reducing or oxidising (see p. 227).

Red is the commonest and the most characteristic colour of bricks; it is the one which, in architecture, gives those fine shades so pleasing to the eye. In order to break the monotony of one single colour, white bricks are frequently mingled with red ones, and designs are executed with bricks whose heads are black. We have seen how these bricks are produced in wood firing (p. 200).

A bluish black colouring may also be given to bricks in the following manner. They are fired in intermittent kilns; when this is finished, the furnaces are filled with bundles of green birchwood having the leaves still on, *all openings are closed*, and a copious smoke is given out which is deposited on the still red-hot products, giving them a black colour with a bluish lustre.

Instead of fagots, oils loaded with petroleum may be burnt. The arrangement of the kiln varies, but one of the most convenient consists of placing funnels in the arched roof of a tunnelled intermittent kiln, and pouring through them on to the incandescent mass tar or oil loaded with petroleum. Care is taken to close all openings beforehand. As the colouring is effected by a deposit of carbon, it is indispensable that all entrance of air should be prevented as long as the temperature is above dark red heat, otherwise the carbon deposit would disappear by combustion.

To obtain a black colouring with bluish metallic lustre, which is the one most esteemed, we must work with strongly ferruginous pastes. For 1000 kilog. of fired products, 3 to 8 kilog. of oil are required, and must be poured in several times at intervals of one or two hours.

At West Bromwich in Staffordshire blue bricks are obtained

by the use of a special purplish clay containing a large proportion of oxide of iron.

The white bricks, which are always slightly yellow, are made of clays containing no oxide of iron; but they are not for that reason necessarily refractory.

Decoration of Bricks. — *Ornamented Bricks.* — Besides the differently shaped bricks of which we have already spoken, bricks with ornaments are also made, which are intended for cornices or entablatures. This result is easily obtained by stamping with a press like the one represented in Fig. 167.

Figs. 258 to 265 show some ornamented bricks of different shapes and sizes according to the uses for which they are intended. Clay by its plasticity lends itself admirably to the reproduction of all kinds of designs, and as, by suitable moulds, the same type may be repeated in numerous examples, this kind of decoration is comparatively cheap.

Fig. 258.

Fig. 259.

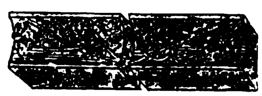



Fig. 260.

Fig. 261.

Fig. 262.

Fig. 263.

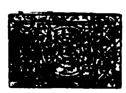



Fig. 264.

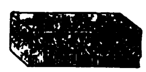
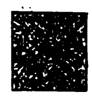



Fig. 265.


Figs. 258 to 265.—Various Ornamental Bricks.

The brick represented in Fig. 263 is intended for a ventilator; in this way the use of those unsightly iron gratings frequently placed at the orifice of ventilating shafts is avoided in façades.

Enamelled Bricks.—Another kind of decoration which, besides a pleasant appearance, gives valuable qualities to the bricks, is varnishing and enamelling; but the manufacture of such products comes under the head of Faïences, and we will postpone further details as to enamelled bricks until we come to the chapter referring to faïences.

Qualities of a Good Brick.—Besides the colour, the importance

of which for facing bricks we have already emphasised, a good brick should be homogeneous, without fissures or flaws, not frost-cracked, easily cut and very resisting.

Homogeneousness is tested by superficial appearance and also by fracture, which should be clean-cut and show a fine close grain without sign of crumbling away.

Regular shape, which depends upon regular dimensions, is, as we have said, necessary to ensure satisfactory dressing, especially when on the surface: the edges should be very sharp.

The non-liability to frost-cracking is an important quality, for without it a building would suffer from the weather. This quality is approximately tested by measuring the quantity of water absorbed by the dried bricks; this should vary from 12 to 16 per cent. of their weight; but this measurement is only an indication, and so is the method of impregnating the brick with a saturated solution of sulphate of soda in order to see if it loses small fragments, which would show its liability to crack.

Direct experiment is the most conclusive; it consists in plunging several bricks into water, and afterwards subjecting them to a temperature of several degrees below zero (*Essai officiel des terres cuites*, p. 381).

Ease of cutting is useful in order that the mason may be able to cut the brick without difficulty to fill up gaps or to complete a layer, etc.

The *resistance* is proportional to the hardness of the bricks. It is recognised by the clear sound which should be given when they are struck together. This resistance is measured directly by making the bricks support greater and greater weights until they are crushed or break, according as we attempt their crushing or fracture. In buildings bricks tend rather to become crushed.

According to experiments which have been made since fairly remote times, a well-fired brick will be crushed under a weight varying from 110 to 150 kilogrammes per square centimetre. This weight is reduced to 90 or even to 60 kilogrammes if the brick is insufficiently fired. These numbers are mere indications, and vary considerably with the manner in which the bricks have been made and the degree to which they have been baked. In

practice, bricks are only subjected to the tenth part of the pressure which would crush them.

The effort required to produce rupture is very much less; subject to the remarks made above, the pressure has been found to be on an average 30 kilogrammes per square centimetre.

The *density* of bricks is also a sign of good quality, because well-blended clays give bricks of very close grain, very homogeneous, and consequently of great density. But here again we must have recourse to direct experiment, for there are certainly bricks which differ in weight and are yet as good in quality. The weight of a well-fired and dry brick of dimensions $.22 \times .11 \times .06$ to $.07$ varies from $2\frac{1}{2}$ to 3 kilogrammes. For the official tests of bricks see the end of Part I., p. 377.

HOLLOW BRICKS.

Hollow bricks, first manufactured mechanically in France by M. Borie in 1850, are bricks pierced longitudinally, transversely, or perpendicularly with cylindrical or prismatic holes which pass from one face to the other parallel to an edge. In France, those most used are pierced longitudinally with prismatic holes.

Manufacture.—The preparation of the clay, the soaking or moistening, is performed in the same way as for solid bricks; impurities such as roots and stones should be carefully avoided, as they would cause a loss in manufacture.

In some machines, all traces of impurity are removed by passing the clay through a sieve. The paste is generally firmer than in the case of solid bricks, since more consistency is required to prevent the brick from losing shape.

The moulding is done by expression machines, the compression of the clay being effected by means of propelling cylinders, screws, or pistons; all these machines are similar to those we have described in speaking of solid bricks, only the dies being different. Figs. 266 to 269 give different views of a die which gives passage to three hollow bricks having eight holes in each. The outer edges of the brick are cut by the die, and to produce

the holes bronze pieces are added which carry well-finished parts of the dimensions of the holes, and these parts keep back the clay. The hollow separating them from the outer edge forms the thickness of the brick. Each row of holes requires a special piece, as may be seen by the view of the inner side (Fig. 267). These pieces are movable, for being of bronze they wear out rather fast, and they must be renewed as soon as the holes in the bricks become too narrow.

Sheet-iron combs are frequently placed against the die above and below the prism of clay; the sharp teeth of these bite into

DIE FOR HOLLOW BRICKS.

Fig. 266.

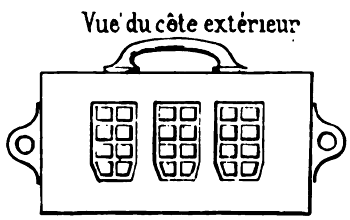
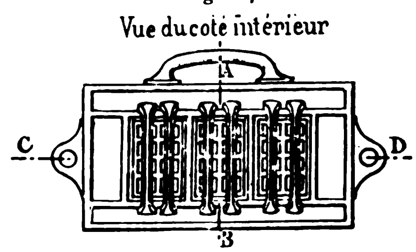


Fig. 267.



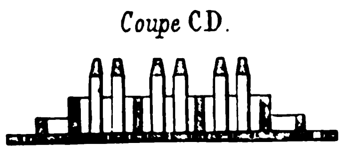


Fig. 268.

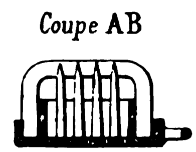


Fig. 269.

Fig. 266.—View of Outer Side.
Fig. 268.—Section C D.

Fig. 267.—View of Inner Side.
Fig. 269.—Section A B.

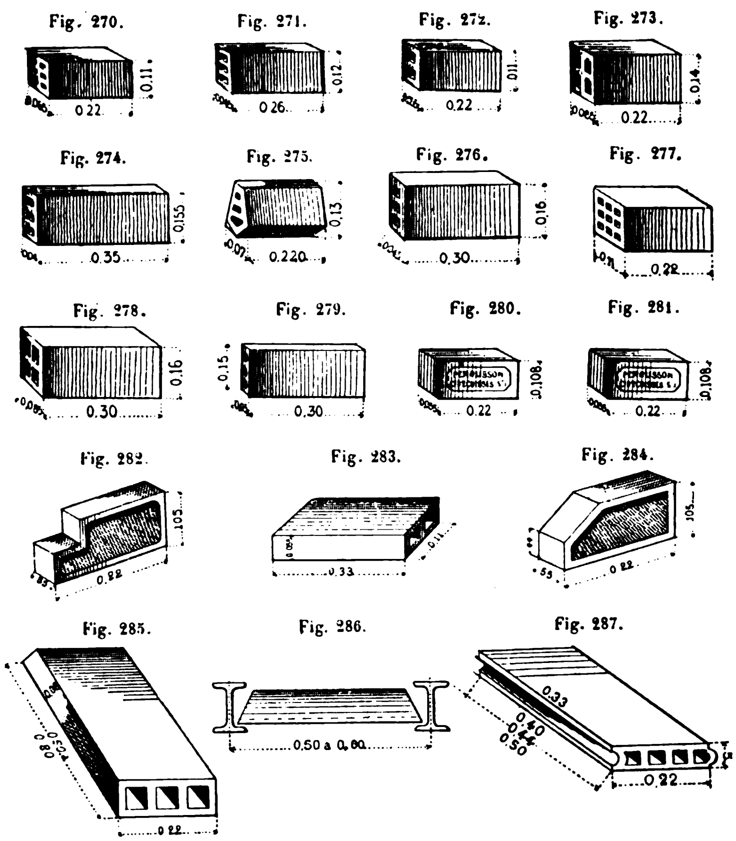
the fresh clay and dig grooves in it which will increase the hold of the plaster or mortar when the bricks are employed for partitions, the commonest use for these products.

The dimensions of the die as well as the distance between the wires of the cutting-table vary according to the direction in which the holes are to lie, as shown in the following table. We suppose a brick which is to be after firing: .22 × .11 × .055—

	Dimensions of the Hollow of the Die.	Distance of Wires.
Bricks pierced longitudinally	.12 × .06	.24
,, ,, transversely	.24 × .06	.12
,, ,, perpendicularly	.24 × .12	.06

As in the case of solid bricks, the same die may pass several bricks at the same time, either the issuing orifices being separated, as in Fig. 266, or there being one single orifice, and the brick being divided, as it issues, by well-stretched wires (Fig. 130).

The dimensions are the same as for solid bricks. Hollow bricks naturally require less clay for their moulding than solid



Figs. 270 to 287.—Various Hollow Bricks (Perrusson and Desfontaines).

ones, therefore large machines of high production are not suitable for this work, machines of moderate production being better.

The *drying* and *firing* of hollow bricks do not differ from those of solid ones, but they require less time and less fuel, hence the sale price is lower.

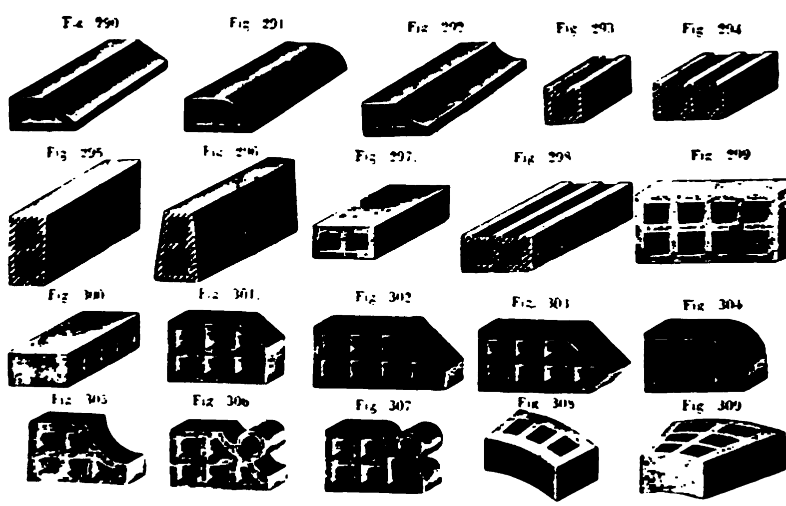
In France, hollow bricks are generally parallelopipeds with holes in the direction of the length (Figs. 270 to 279, 295 to 297), but in Germany, where nearly all buildings are of brick, hollow bricks of the same shape as the solid bricks are used, and we find bricks with cut off corners (Figs. 301 to 303),

LAPORTE "HOURDIS" (Montchanin Manufacture).

Fig. 288.—For Arched Flooring.

Fig. 289.—For Straight Floor.

rounded bricks (Figs. 304, 305), and finally moulded bricks (Figs. 306, 307). These products being used in facings, the holes must be placed perpendicularly to their large surface; when they are headers, they may be perpendicular (Fig. 299) or transverse (Fig. 300). Finally, bricks with cut off or rounded



Figs. 290 to 309.—Hollow Bricks of Different Shapes (German Manufacture).

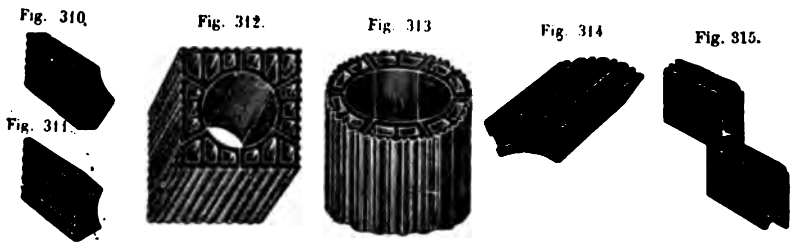
corners are made having holes in the direction of their length (Figs. 290, 291, 292).

"À couteau" bricks, curved bricks for arches and chimneys, are also made with holes (Figs. 296, 308, 309).

In giving to bricks special shapes like those in Figs. 310,

311, and 314, different pipings of great diameter are produced (Figs. 312, 313).

Hollow bricks are much used for the arches of I-shaped iron floorings (Fig. 316). We see from the figure that the beginning



Figs. 310 to 315.—Hollow Bricks of Special Shapes.

of the arch does not fit the shape of the iron on account of the wings; therefore, to remedy this inconvenience, bricks of special shape are manufactured called "briques à sommier" (Fig. 275).

Decoration of Hollow Bricks. — Hollow bricks are often

Fig. 316.—Arch of Hollow Bricks.

enamelled for partitions or facings of ordinary walls; as in the case of solid enamelled bricks, we will postpone discussion of these until the chapter on Faïence.

Dimensions and Shapes.—The dimensions of hollow bricks are much more varied than those of solid bricks, as is shown by the following table giving current sizes.

	Holes.		Holes.
.045 × .15 × .22	2 or 3	.045 × .15 × .3	2 or 3
.045 × .16 × .22	2 or 3	.045 × .16 × .3	,, (Fig. 276)
.055 × .11 × .22	2 or 4 (Fig. 272)	.07 × .16 × .3	4 or 6
.065 × .11 × .22	4 or 6 (Fig. 270)	.07 × .21 × .3	,,
.065 × .16 × .22	2, 4, or 6	.08 × .16 × .3	,, (Fig. 278)
.07 × .15 × .22	,,	.10 × .11 × .3	6 or 9
.08 × .16 × .22	4 or 6	.11 × .11 × .3	,,
.10 × .12 × .22	6 or 9	.11 × .16 × .3	6, 9, or 12
.11 × .11 × .22	9 (Fig. 277)	.11 × .22 × .3	,,

Besides the above-mentioned bricks, some are also made of special shape (Figs. 285, 286, 287), .22 m. broad, of length varying by centimetres from 50 to 80, and of thickness varying from 5 to 11 centimetres. They are used to fill up intervals between the I-shaped irons of floorings (Fig. 286) or to raise partitions (Fig. 315). When the I-shaped iron pieces have a considerable height, special hollow products called "hourdis" are substituted for these bricks. Those most used are the Laporte "hourdis," so called from the name of their inventor (Figs. 288, 289). Their length is .33, and their thickness depends upon the height of the I-shaped iron bars. Their upper surface is placed on a level with the latter.

Qualities.—These are the same as those required for solid bricks, that is to say, that when used in facings they should have a uniform colour and sufficient hardness, that they should not be liable to crack, and should be of regular shape. The colour and resistance of the inside need not be so carefully supervised.

According to the experiments of Hervé Mangon, the resistance offered by hollow bricks to crushing presents a curious difference according as the pressure is parallel or perpendicular to the direction of the holes. Thus, whereas a *mean weight of* 24 *kilogrammes* per square centimetre applied to a brick laid flat is sufficient to crush it, a weight of about 100 *kilogrammes* is required to crush the same bricks placed on end. Deducting the hollows formed by the holes, the pressure necessary to crush the bricks is, per square centimetre of the solid parts, respectively from 80 to 150 kilogrammes. That is to say, that a hollow brick under a crushing pressure perpendicular to the holes offers almost as much resistance as a solid brick. This difference of resistance is similar to that noticed in the case of wood, which is less resistant with the grain than across the grain. It is also a valuable indication to the builder, who should take it into consideration whenever he uses hollow bricks before exercising strong pressure.

For the official tests, see the end of Part I.

§ 3. APPLICATIONS—HISTORY AND USES.

(1)—*History.*

The discoveries of scientists have shown that even in the geological periods, that is to say, long before historic times, the plastic properties of clay were utilised by man for the manufacture of various objects. Pieces of pottery have been found contemporaneous with the stone age in the lake dwellings of Switzerland and with the bronze age in Denmark. In Europe, Asia, Africa, and America similar evidence shows that the use of clay was general on the globe and that it dates from the most distant antiquity.

Were the first objects made of clay utensils called potteries from the Latin *potum*, meaning drinking-vase (Brongniart), or those parallelopipeds which we call bricks from the Anglo-Saxon *brice* (Littré)? The question is a difficult one to answer: one thing is probable; that is, that raw bricks, namely those only dried in the sun, must have preceded bricks baked by fire.

As might be expected, those countries whose soil is of a clay nature have especially used bricks as building material. Accordingly the regions near the mouths of large rivers, the alluvions of which have formed valleys and attracted man, are remarkably rich in interesting vestiges of brick monuments.

The plains of Asia, the banks of the Tigris and Euphrates, the valley of the Nile in Africa, are examples of this. We find, on the other hand, no traces of the use of brick in certain parts of Norway and Sweden, where wood is almost exclusively used for the construction of dwellings.

It is evident that the first bricks must have been roughly fashioned, but clay lends itself so easily to modelling, that this primitive manufacture must have rapidly improved. Besides, as the taste for ornamentation grew with the advance of civilisation, attempts were made from the earliest times to decorate the baked clay by enamelling it with brilliant colours. Finally, the plasticity of the clay, which takes any shape, led to the modelling of plain

or enamelled terra-cotta ornaments, which were used to decorate buildings, and which are now found among their ruins. We will now give a sketch of the principal discoveries which form the foundations of the history of the applications of brick in ancient times.

Asia.—The valleys of the Tigris and Euphrates offer to archæologists numerous and important ruins of brick edifices. Of Babylon, that immense Chaldean city founded by Nimrod more than twenty-six centuries before our era, so celebrated for its riches and for the remarkable works carried out under the orders of Semiramis the Beautiful, there remains nothing to-day but a large collection of ruins forming a series of eminences, 10 kilometres long, on the banks of the Euphrates.

An examination of some of these ruins has shown the important part played by brick in the construction of Babylonian buildings. The greater part of these buildings was formed of raw bricks, used when fresh and thus rendered adherent in spite of the absence of mortar. But there are also many fired bricks to be found, most of them bearing inscriptions in cuneiform characters which appear to have been made by stamping. They are very hard, of a reddish colour, and have the following somewhat large dimensions: about .3 m. to .5 m. and .06 m. to .07 m. in thickness.

The most remarkable ruin built of fired bricks crowns an eminence on the right bank of the Euphrates; it consists of a fragment of wall 8 to 10 metres high and 6 metres broad. The layers of the bricks, which are almost completely vitrified, and the cement joining them, can be distinguished; the dressing is regular and well finished, the bricks are .35 × .32 × .072 in size.

Some archæologists see in these ruins the remains of the famous Tower of Babel, others consider that they belong to the Temple of Belus.

According to the Greek historian Herodotus, the bricks used to build the high walls of Babylon, which are attributed to Semiramis, were made of clay extracted on the site of those walls.

The exploration of the ruins of Nineveh, Babylon's rival and

neighbour, has shown that clay was also the principal building material in the Assyrian monuments: fired bricks were used for facings and decorations, for they were often enamelled; the bases were of limestone.

Other important ruins of ancient cities of Asia Minor have also exemplified the great part played by clay, fired or raw, in the construction of their buildings.

In *Persia*, it is probable that the use of brick was introduced by the Assyrians, who for a long period held Media (a part of Persia) under their rule.

Many fragments of terra-cotta have been found in the ruins marking the site of the famous Ecbatana, capital of Media, and of Susa, where the Dieulafoy mission has excavated the palace of the ancient Persian kings.

In all these ruins numerous bricks have been found, some whole, some broken, and coated with variously coloured enamels, which show the importance of these materials in Assyrian, Chaldean, and Persian architecture. We shall return to this subject later on.

The use of brick continued under the dynasty of the Sassanides, which was founded by Artaxerxes in the second century before our era, and destroyed by the Arabs towards the seventh century. But the quality and decoration of the bricks were no longer those of ancient times, and, although examples remain to the present day, the bricks have neither the dimensions nor the remarkable appearance of the ancient products.

The pagodas of *India*, while not as ancient as Babylon and Nineveh, are also examples of the use of brick in public buildings. The ruins which have been discovered do not seem to date back beyond the first centuries before our era; the existing buildings, whether well or badly preserved, date from our middle ages.

As far as we can tell, *Chinese* builders have scarcely ever, from the most distant antiquity, used anything but brick and wood, to which later on, in the centuries immediately preceding our era, they added porcelain, a new application of pottery to architectural art. The famous Great Wall, which, according to some historians,

dates from the 3rd century B.C., is in several parts built of brick: the same may be said of certain fortified enclosures of Chinese towns, which are made of clay sometimes simply baked in the sun, sometimes fired and decorated.

Africa.—The valley of the Nile, in Egypt, like those of the Tigris and Euphrates, offered in its slime deposits materials suitable for the manufacture of bricks.

From the raised inscriptions on bricks found in different places, it would appear that these products of the industry of the early Egyptians date from the 15th or even the 16th century B.C. The numerous examples which we possess, both of bricks and pottery, prove that not only was the art of firing bricks well advanced in Egypt in those early days, but that enamelled pottery was also known.

We read in Exodus (chap. v., verses 7 to 19) that one of the numerous labours imposed upon the Hebrews by the Egyptians was the making of bricks. A painting found in a tomb at Thebes shows the manner in which they worked: two slaves, whom we take to be Israelites, are drawing the slime from a basin; another works up the clay and probably adds straw to it; and a third slave moulds the brick in a mould similar to those which the Egyptians still use at the present day.

Although the firing of bricks was known to that nation, raw bricks were used in large quantities, and monuments built of them, such as certain pyramids of Dahschour dating from the 3rd dynasty, have remained intact to our day, thanks to their facings of stone. These bricks were not used fresh, as in Assyria, but were dried in the sun.

Why is it that in countries like Asia Minor and especially Egypt, where stone, porphyry, and granite were abundant, and in which economy would scarcely have influenced the Governments, we find such a relatively large consumption of raw or fired brick in their public monuments?

America.—Although the ancient history of this part of the world is not as well known to us as that of the countries previously mentioned, we find in the ruins of ancient monuments an index of the civilisation attained by the inhabitants of the

country before its discovery by Christopher Columbus. As an example of brick construction we may mention the pyramid of *Cholula* in Mexico, whose horizontal dimensions are greater than those of the great pyramid of Egypt, and which is built of raw bricks bound together with a clay mortar.

In *Peru*, ruins of palaces are found, built of peculiar bricks which do not seem to be baked and yet offer great resistance to the inclemencies of weather; they have remained intact, heaped up on the ground. We can understand that masonry constructed of such materials is of great solidity, and this is confirmed by the examination of some of the ruins which, in the parts still standing, offer as great a resistance as if they were built of very hard stone. This method of hardening bricks seems to be lost, for the modern bricks of those countries have no longer that remarkable quality.

The tombs explored in the valley of the Ohio also prove the antiquity of the use of baked clay in the New World.

Europe.—Instead of taking the history of each country separately, it will be better to follow the different periods of architecture from the Greeks and Romans in modern times.

Greek Architecture.—The use of brick in Greek monuments has only been proved by the writings of authors and the numerous traces found almost everywhere, for no single brick building exists which can be affirmed to be of Greek origin. But according to the works of the Roman architect Vitruvius (2nd century B.C.), the Roman author Pliny (1st century), and the Greek geographer Pausanias (2nd century), a certain number of temples, and other monuments of a date anterior to the Roman domination, were built of raw or baked bricks. Certain parts of the walls of the Acropolis at Athens contain these materials.

According to Vitruvius, there existed three kinds of Greek brick: the *didoron* ($.3 \times .15$); the *tetradoron* ($.3 \times .3$), used in special work; and the *pentadoron* ($.37 \times .37$), used in public works.

Roman Architecture.—In contrast to the Greeks, those great builders, the Romans, have left as traces, wherever they have passed, remarkable and imposing monuments which offer numberless examples of the use of bricks.

The first materials used by the Romans must have been raw bricks, although none have been found in the remains of monuments of that period; but Vitruvius describes their manufacture with details from which our brick-makers may still derive benefit. The same author is silent as to the time when fired bricks first entered into Roman architecture, but it is certain that their use dates from a fairly distant period. The finest specimens of the monuments in which brick plays an important part are of the early years of Imperial Rome, and imposing ruins remain to prove their solidity of construction.

Roman fired bricks were of various shapes and sizes, for they were often made to fit the place they were to occupy in the buildings. Generally they were square, the large ones having about .6 edge and .055 thickness, the medium .445 and .05, and the small .215 and .04. Large square bricks, .65 and .05 (ancient house of Civita Vecchia), and triangular bricks for the facing of block masonry have also been found. At the period when brick-making reached its apogee (1st century), it was carried out with the greatest care under the supervision of the Government, who required the maker's mark to be on the products. These marks, some of which bear the names of great personages who were proprietors of brickworks, were a guarantee of good quality, and in consequence have acquired historical and archæological interest, for from the reign of Trajan (1st century) the names of the consuls were added to those of the proprietor and maker; thus by examining these marks it is easy to determine the age of a Roman monument.

The Romans, who were skilful builders, used brick in all parts of their constructions. In the walls called "medium and small dressed," the masonry was formed of rubble enclosed between two facings of brick or ashlar-work, and comprising a variable number of alternate layers. Among examples of this class of construction may be mentioned: the Herculaneum gate of Pompeii, the fortified castle of Babylon in Egypt, and finally the hot baths of Caracalla, all works dating from the early centuries of the Roman Empire. From the 3rd century onwards this use of alternate layers of bricks and stones of various

dimensions became more frequent; numerous Gallo-Roman buildings were constructed in this manner. Bricks alone or accompanied by key-stones form the arches of doors and windows. The Romans frequently used brick arches hidden in the thickness of the wall as a means of consolidating and distributing the pressure on certain points. They also made a general and remarkable use of arches of brick, or more frequently brick and rubble, to cover large spaces like the baths and the palaces of the Cæsars.

Roman aqueducts also present examples of the use of brick in arches and facings. Such are the ruins of Nero's aqueduct at Rome, and the aqueducts of Lyons, Arles, Mayence, etc.

For interiors, brick masonry was generally covered with stucco, and such materials were even used for building isolated columns as has been shown in the basilica at Pompeii. Finally, combinations and arrangements of bricks have been used by the Romans for pilasters and cornices to adorn several buildings of ancient Rome.

The history of human arts shows that, whatever may be the nation, country, or epoch, they pass through three periods: development, apogee, and decadence. This is what happened in the case of Roman brick-building. The apogee was reached in about the 1st century A.D., contemporaneously with the first emperors; then came the decadence, which was marked by the little care given to the construction of masonry. While the joins were scarcely visible in the fine ancient edifices, now they gradually increase until at last masonry came to be composed of materials of all shapes and dimensions. The thickness of the joins is a means of ascertaining the age of Roman monuments, and is found by counting the number of bricks in a given length: in the 1st century there were 10 bricks in .3 metre (arcades of Nero); in the 2nd century, 8 bricks (Adrian's villa); in the 3rd, 6 bricks (Aurelian's wall); 4th century, 4 bricks (circus at Mayence).

In concluding this historical sketch of the use of bricks by the Romans, we need hardly add that remains of pottery are found in all parts of their immense empire.

The architecture of the Christian monuments, built almost everywhere between the 4th and 10th centuries, was inspired by that of the Romans; we frequently find the alternate use of bricks and stones or rubble, for example, in what remains of the walls of Saint-Laurent's Church at Rome (4th century), in the churches of the Basse-Œuvre, at Beauvais; of Vieux-Pont-en-Auge (Calvados); of Saint-Mesmin (Loiret); of Saint-Martin d'Angers (9th century), etc. etc.

Byzantine Architecture.—As the name suggests, this originated at Byzantium; its chief characteristic is the almost exclusive use of bricks as decorative objects. The materials resemble Roman bricks and usually bear inscriptions of various kinds. They were used with or without casing for walls and also for arches; for instance at Saint-Sophia in Constantinople, the cupola of which, 35 metres in diameter, is built of bricks.

The Greek churches of that period are adorned with very varied designs, worked in different dressings of bricks. This kind of decoration, which has a quite distinctive character, is also found in certain countries whose geographical positions have subjected them to the influence of Constantinople; for example, in Roumania and Russia.

In the latter country, Byzantine architecture has undergone transformations due to the influences of Persian and Hindoo art, but brick still remains the principal element in both construction and ornamentation.

Turkish Architecture.—The Arabs did not impress upon the nations whom they conquered such a personal character as did the Romans. While the latter gave to vanquished peoples their laws and their customs, the Arabs, on the other hand, were rather influenced by them themselves. As regards architecture, this difference is shown by the diversity of Turkish monuments according to the countries in which they were built. The architects allowed themselves to be influenced first by Byzantine art, and used the materials, stones and bricks, of which existing edifices were constructed.

In Egypt, the Turkish architecture was mainly Arab; in the mosques of the 9th and 10th centuries, brick, afterwards

covered with stucco, plays a great part in the construction of the walls. The invasion of the Iberian peninsula by the Arabs introduced the *Moorish style*; and pottery was used extensively for building and adorning those magnificent edifices which still stand for the admiration of all. Such are the mosque of Cordova (8th and 9th centuries) and the *Alhambra* of Grenada, in which brick and faïence form a large part of the ornamentation.

Asia Minor and Persia, in turn dominated by the Arabs, the Turks, and the Ottomans, had at first their religious buildings, which were afterwards changed into mosques; then the invaders raised other edifices in which we find Byzantine art modified by Arab or Persian taste. The most interesting of the monuments still remaining, such as the *Green Mosque* at Nicea (8th century); the *Blue Médrécé* or religious school at Konieh in Lycaonia (12th century); the mosque of Baba-Souctah at Ispahan, etc., all exemplify the use of bricks of all shapes and varieties: raw, fired, enamelled. But their chief charm lies in the use of faïence plaques decorated with that taste and skill which have made Persian faïence one of the finest manifestations of decorative art.

Romance Architecture.—Being derived directly from Roman art, this is especially developed in the north of Italy, in Lombardy, the region in which there was such an extensive use of brick. The chapel called *Saint-Aquilin's* and the church of *Saint-Ambroise* (4th and 5th centuries) at Milan have walls and arches made of brick. The cupola of the latter building is crowned by a very curious terra-cotta cornice; it stands back a good deal from the remainder of the building. Fig. 319 represents a part of it.

At Pavia, the church of *Sainte-Euphémie* (5th century), the church of *Saint-Michael* (11th century), the church of *Saint-Théodore* and *Saint-Lanfranc* (11th and 12th centuries), are almost entirely built of bricks; they offer remarkable examples of terra-cotta building and decoration, either alone or combined with stone and even marble.

Brescia, Venice, Padua, Pavia, and Crema with its cathedral almost entirely of brick, also possess monuments in which this material predominates. The architects of the period, by

variety of form, contour, and colour, were able to avoid that uniformity and monotony always presented by large surfaces built of the same material. Fig. 320 represents a fragment of the crown of the frontal of the Crema Cathedral (13th and 14th centuries).

The celebrated Carthusian Monastery at Pavia (1396; Fig. 317) is a brilliant example of the skill of the builders of that period. Brick walls, alone or alternated with stone, friezes,

Fig. 317.—Interior of the Carthusian Monastery at Pavia.

cornices, terra-cotta sculptures, all have resisted the march of time.

The state of preservation of these buildings, most of which are anterior to the 13th century, shows that brick and terra-cotta bear easily the destructive action of time.

The north of Italy is very rich in brick-built work, and the neighbouring countries certainly do not offer as many examples of constructions of that kind. Nevertheless the Roman system of building in brick and stone lasted a long time, especially in Gaul, during the Gallo-Roman and Merovingian periods. Then,

from about the 9th century, brick buildings disappeared from those countries in which stone was abundant, but persisted where it was lacking, as in Languedoc. The church of *Saint-Sernin* at Toulouse (Fig. 318), which dates from the 11th century and was partly restored by Viollet-le-Duc, is almost entirely built of bricks, stone being reserved for some special uses; by its beauty and harmonious combination it presents a striking example of what can be obtained, without sculpture, with ordinary materials arranged in well-calculated proportions. The belfry is of brick, with little stone columns at the angles; it has five

Fig. 318.—Saint-Sernin's Church at Toulouse.

storeys of double bays, three arched and two terminated by triangles at their upper part. It resembles the belfry of the Jacobin convent in the same town, one storey of whose bays is represented in Fig. 322.

Gothic Architecture.—In Italy, the change from the full to the pointed arch has been effected by successive transitions, and some churches combine Romance with Gothic style. The north of the country is again richest in brick monuments dating from that period; but many towns of other provinces have also brick buildings which, without having the importance of the Lombard churches, are still none the less interesting. Bologna, Ferrare,

Lucques, Pisa, Ravenna, Rome herself, possess towers, palaces, houses, built of brick sometimes combined with stone. Nearly everywhere terra-cotta is skilfully interspersed among the bricks to produce very harmonious ornamentations such as those of

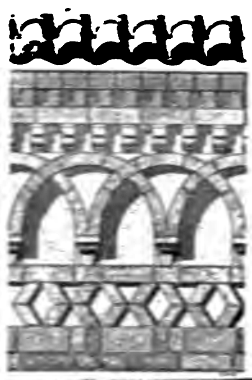


Fig. 319.

Fig. 320.

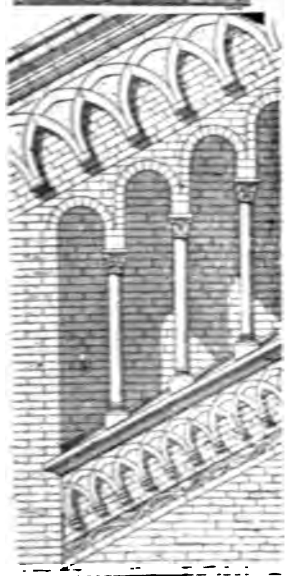
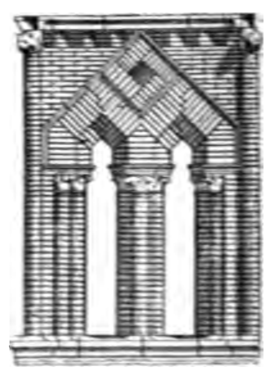


Fig. 321.

Fig. 322.



Figs. 319 to 322.—Specimens of Brick and Terra-cotta Decoration (11th to 15th Centuries).

the church of Santa Maria del Carmine at Pavia (14th century; Fig. 321). The south of France also offers some very interesting types of Gothic brick buildings. Toulouse is especially rich in monuments of this kind, and we may mention the old Jacobin

convent (end of 13th century), the *Cordeliers* church, the *Capitol*, and the *Saint-Raymond College* (14th century). The cathedral of Albi (13th and 14th centuries) contains nothing but brick,

Fig. 323.—Windows of the Hotel du Vieux-Raisin at Toulouse.

except the mullions of the windows and some parts of the choir; it is one of the most imposing of brick buildings. Its tower, which is flanked by turrets, has the appearance of a keep, and rises 78 metres above the ground. The church of Simorre (Gers)

MAISON DE TRISTAN AT TOURS.

Fig. 324.—Exterior.

Fig. 325.—Interior.

is another example of a church entirely built of brick, and with the appearance of a military construction; it dates from the 16th century.

In private architecture, we find at Toulouse, Alby, Montauban, Caussade, numerous houses of which brick is the chief material

Fig. 326.--The Belfry at Bruges.

(Fig. 323). In the middle and north of France, bricks were not at that period used as much as in the south, but they were frequently used for filling in the exterior of timber-framed houses,

especially in the 15th and 16th centuries. The architects understood how to utilise bricks with skill, even in works for which such material did not seem at all suited. The house of Tristan at Tours (Figs. 324, 325), built of bricks and stone, contains a winding staircase, which can be seen through the open window (Fig. 325), and of which the newel, the arch, the filling of the steps, and the risers are brick. Only the hand-rail is of stone and the edges of the steps of wood.

In Germany, at Dantzig, Lubeck, Marienburg, Schwerin, we

Fig. 327.—Church of Santa Maria della Grazie at Milan.

find some very interesting public and private brick buildings of the 12th and 13th centuries.

Belgium and Holland possess some remarkable and important brick structures, among which must be mentioned the fine belfry at Bruges (Fig. 326), 100 metres high, and dating from the 13th century, and the Antwerp market, an immense construction of the 15th century, made of bricks and stones. England, which at the present time uses so many bricks, did not begin to do so until the 14th and 15th centuries; the oldest brick structure, besides Roman remains, is said to be the Little Wenham market-hall, which dates from the end of the 13th century.

The dimensions of the bricks used during the Middle Ages are somewhat variable; those of the cathedral of Albi are .35 × .27 × .05; others, also in the south of France, are .35 × .25 × .06 and .40 × .28 × .05. In Touraine they are stated to be .25 × .115 × .055, very nearly the present size.

Renaissance Architecture.—The use of brick is continued. Sometimes architects utilised it for the body itself of the building, as in *Saint-Peter's* at Rome, of which the cupola and its supporting walls are of brick covered on the inside with stucco, on the

Fig. 328.—Farnèse Palace at Rome.

outside with travertin; *Sainte-Marie-des-Fleurs* at Florence, etc. Sometimes they leave it visible and use it for adorning their work, as in the *Chancellerie Palace* at Rome, built by Bramante at the end of the 15th century, the church of Santa Maria della Grazie de Milan (Fig. 327), attributed to the same architect; the *Farnèse Palace* (Fig. 328), restored by Michael Angelo and San Gallo in the 16th century.

France was enriched during the Renaissance by magnificent edifices in which brick, alone or combined with enamelled terracotta, formed one of the principal adornments. One of the most remarkable of these buildings was the castle of Madrid at the

gates of Paris, which was built by Della Robia during the 16th century but has now disappeared.

Fortunately the châteaux of Saint-Germain and Fontainebleau still remain to show the effect produced by the combination of stone and brick. The charming Louis XII. wing of the château of Blois (Fig. 329) and the château d'Anet also deserve notice.

Numerous hôtels and private houses were also built of stone and brick during the Renaissance.

England, Germany, Belgium, and Holland continued to use brick for building under the Renaissance. Many curious houses and remarkable edifices might be mentioned which take their

Fig. 329.—Louis XII. Wing of the Château de Blois.

originality from the use of brick. Bruges is particularly rich in constructions of this kind; its houses have a characteristic appearance (see the right of Fig. 326).

Architecture of the 17th and 18th Centuries.—Under Henry IV. and Louis XIII., stone and brick were still used for public buildings, and slate was sometimes added to produce such picturesque effects as can be seen in the Henry IV. wing of Fontainebleau Palace, and in the châteaux of Monceaux and Verneuil built for the fair Gabrielle and the charming Henriette d'Entragues. The buildings in the Place des Vosges and the Place Dauphine in Paris, which date from the same reign, and

the central part of the present castle of Versailles, built under Louis XIII., are also interesting examples of the use of stone and brick.

The reign of Louis XIV. offers, if we except the Palais Mazarin, few brick and stone structures. The use of brick for the ornamentation of public buildings ceased entirely from the middle of the 17th to the middle of the 19th century. But the people of the north and south of France continued to utilise it for private dwellings.

The use of brick continued to spread and increase in England

Fig. 330.—School of Architecture at Berlin.

after the Renaissance, and the 17th and 18th centuries have left some fine structures in which may be noticed bricks ornamented by stamping after firing and also by cutting after being laid in position.

Architecture of the 19th Century.—Germany.—This is one of those countries in which bricks are the most important of building materials. Many bricks ornamented with designs in relief are made there for use in decorating buildings. The Schinkel School of Architecture (Fig. 330) and the Werder

church in Berlin are remarkable examples of that kind of construction in which terra-cotta is used side by side with brick.

England.— Baked clay under all forms and colours is here used almost exclusively; London, we may say, is built entirely of brick, but it is not embellished thereby, for the modern secret of brick architecture does not seem to be yet discovered in England. Many Renaissance imitations are built, and still more commonplace repetitions, but no stamp of originality or beauty is found on the modern brick buildings. We must, however, specially

Fig. 331.—Natural History Museum of London.

mention the new Natural History Museum in London (Fig. 331), a vast construction entirely built of stone-coloured brick, which is left uncovered both inside and outside. The general effect is most imposing.

Belgium.—This is the great brick country, and it is used there in all constructions: public buildings, houses, military works, civil works, etc. More than a thousand million bricks have been used in the extension and management of the port of Antwerp. This large consumption is only possible because of their low price. Ornamented bricks are also utilised for the decoration of houses.

Spain.—As in Belgium, the cheapness of architectural pottery, and especially of brick, has stimulated the trade both in ordinary and decorated products.

Holland.—This country being unprovided with building-stone, it is only natural that the brick manufacture should be highly developed in it. Thus we find on the banks of the large rivers, wherever numerous beds of clay are accumulated, huge brickworks which supply the bricks necessary for house-building, canals, side-walks, roads; for everything is made of brick, even the mouldings which take the place of stone.

France.—Whole towns in the north and south are built of uncovered bricks. Elsewhere they are only used in the interior for separating walls and fillings. But of late years a movement in favour of pottery has been observed. In Paris, several recent buildings offer examples of the combined use of iron and brick (Halles centrales, markets, etc.); of iron, brick, and terra-cotta (Pavillon de la Ville de Paris); or of iron, stone, terra-cotta, and brick (Collège Chaptal, Lycée Sévigné, Museum). The exhibitions of 1878 and 1889 have shown the decorative resources offered by the use of ordinary brick. Enamelled brick is also more extensively used (Hôtel des Téléphones).

North America.—The United States consume an enormous quantity of bricks, and all their gigantic many-storeyed edifices are built of that material.

Brick is the principal if not the sole element in their immense railway stations, their colossal docks—in fact, in all those stupendous works which, if not showing great artistic merit, are at least executed with the greatest care.

(2) *Use of Bricks.*

Walls.—The construction is more or less well finished according as the facing is to be visible or not, but the principles on which building is based do not change. These principles are: to raise the wall perfectly perpendicular, and to interrupt the joins as much as possible both in the height and thickness of the wall.

Bricks are arranged endways and lengthways, that is to

say, that their length is sometimes perpendicular, sometimes parallel to the direction of the walls. This arrangement is intended to avoid the continuity of the vertical joins in two consecutive rows; this interruption should be frequent in the upright joins.

It will be understood that there are many possible ways of combining the ends and sides; and this allows of varied designs being made by the use of bricks of different colours. We must, however, reject every combination which does not satisfy the above-mentioned conditions. It is beyond the province of this work to examine in detail every method used, and we will merely mention (Figs. 332 to 335) the most common ways of building a wall whose thickness is the length of one brick.

Fig. 332.

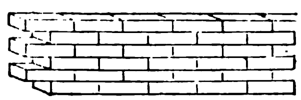
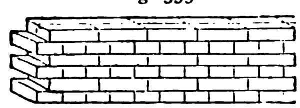


Fig. 333.



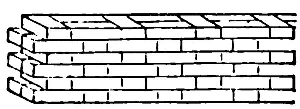


Fig. 334.

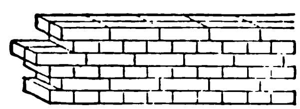


Fig. 335.

Figs. 332 to 335.—Various Systems of Wall-building.

In thicker walls, the possible arrangements of the bricks are infinite, and we must choose those which give the best cohesion in each direction by interrupting the joins as much as possible. If the thickness of the wall allows of it, we begin by erecting two facings, and fill the hollow with bricks placed endways; then, every five or six layers, we place two layers of bricks diagonally and crossed, thus ensuring great cohesion.

To build a wall, we begin by erecting the two corners, quite vertically to the height of a few layers; then, between these two angles, we stretch a cord horizontally above the first layer. We place the bricks on a bed of mortar, and then press upon them with the hand while giving them a slight up-and-down motion so as to compress the mortar to its least thickness. Bricklayers generally effect this by striking the bricks with the edge of their

trowel, but this will only do for facings; for insides the other method is more rapid. The upper edge of the bricks should follow the cord exactly. If their thickness is not uniform, the thickest ones are pushed down on to the mortar so that the upper surface of the row may be level and horizontal. The masonry is completed throughout the thickness of the wall, and when the layer is finished, the cord is raised to the height of the next, and the work continues.

The thickness of the joins naturally depends upon the fineness of the mortar, the uniformity of the bricks, and the thickness of the wall. With cement and well-pressed bricks we may succeed in making joins of only .002 to .003 (about $\frac{1}{10}$th inch), with very fine mortar .006 to .007 ($\frac{1}{4}$ in.), and in ordinary brick-masonry from .012 to .015 (about $\frac{1}{2}$ in.).

The bricks being always spongy, it is better to water them all together before they are used, as otherwise they will absorb some of the water of the mortar.

Finishing the Joins.—When the masonry is completed, we proceed to finish off the joins. In high-class work, when the brick is visible, its fine red colour is brought out by washing it with dilute hydrochloric acid; in this way all the stains of mortar or other substances are removed. Then the joins are hollowed out to a depth of half an inch or so with a special iron hook, cleaned, brushed, and sprinkled with water, after which a specially prepared fine mortar is introduced with a little pointed trowel. When this has become fixed, it is pressed with a polisher to smooth its surface. If fancy joins are required, they are cut in hollow or relief with a special iron tool. Hollow joins are, as regards durability, to be preferred to the projecting so-called "English" joins. More variety may be given to the general appearance by colouring the mortar used.

Arches.—The construction of arches of brick may be as much varied as that of walls; the same precautions must be observed for the joins, which must be perpendicular to the surfaces of intrados. In this way each part of the arch forms a corner, and the whole can keep in position without mortar. When the thickness of the arch does not exceed the length of

a brick or a brick and a half, it is built as an ordinary wall, the intrados being dressed either with endway or lengthway bricks alone, or with endway and lengthway bricks, the choice of arrangement being subordinated to the solidity of the whole. If the thickness is greater, several methods can be used; for instance, several arches each of the thickness of a brick or a brick and a half may be arranged, independent and one over the other. In England a series of superimposed arches each of one brick sideways is preferred, whatever be the thickness.

When the extrados of the arches remain visible after their construction, the dressing must be carefully done; for that purpose the position of the joins, according to the thickness of the bricks and the system chosen, is marked out on the semicircle, bearing in mind that there must be an odd number of layers, on account of the one serving as keystone.

The edges of the bricks being placed normal to the intrados, it follows that the join is thicker at the extrados than at the intrados. It is to avoid this inconvenience that bricks called "corner" and "knife-edge" are made (Figs. 235, 236).

The dressing of special arches, vaulted, annular, conical, spherical, cloister, etc., presents no great difficulty.

Flooring arches are generally made of hollow bricks, and the dressing of them is quite simple.

Paving.—This is done with special bricks, very hard and sometimes vitrified. Their surface is rough or striated when they are used flat (Fig. 251), and bevelled when placed on edge (clinkers) (Figs. 336, 337, 338).

The bricks are laid on a bed of mortar placed where the paving is to be done and sloped for the proper draining off of water. The adhesion of the bricks to the mortar is increased by the use of fluted bricks (Fig. 341).

For stables and wash-houses where large quantities of water are thrown down, special bricks (Fig. 343) are used, which, placed end to end, form a trench and so help the water to run off.

Bricks in the shape of gutters (Fig. 339) are also made to collect the moisture on the pavement (Fig. 342), lateral hollows (Fig. 340) cut in some of the bricks allowing the water to come

Fig. 336.

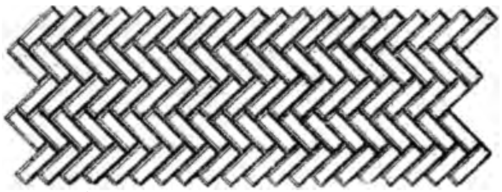


Fig. 337.

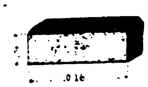


Fig. 338.

Fig. 339.

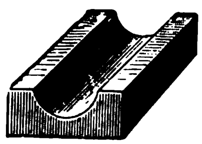


Fig. 340.

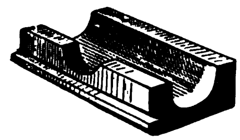
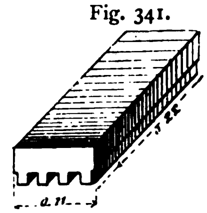


Fig. 341.



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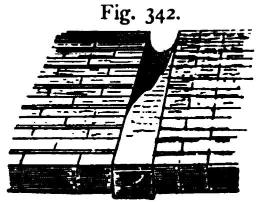


Fig. 343.

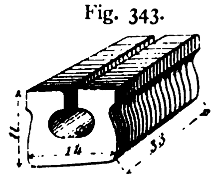
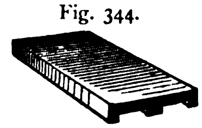


Fig. 344.



Figs. 336 to 344.—Various Paving Bricks.

Fig. 345.

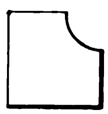


Fig. 346.

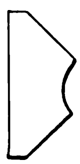


Fig. 347.

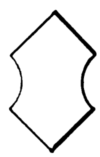


Fig. 348.

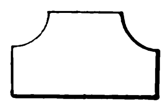


Fig. 349.

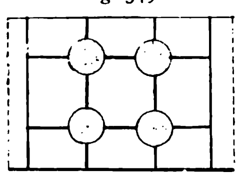


Fig. 350.

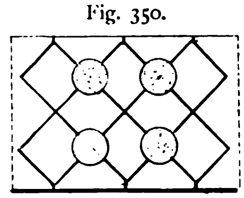


Fig. 351.

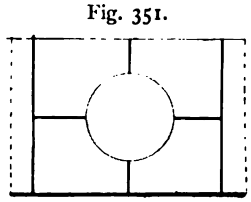
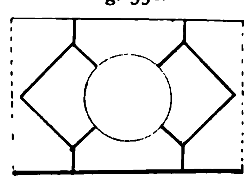


Fig. 352.



Figs. 345 to 348.—Gourlier Bricks for Chimney Conduits.

Fig. 349.—First Layer. Fig. 350.—Second Layer.

Fig. 351.—First Layer. Fig. 352.—Second Layer.

in from other directions. These kennel-stones are either open or closed with a flat brick (Fig. 344).

Chimney Conduits.—Besides the hollow pottery conduits, called "boisseaux" and "wagons," special bricks are used, called Gourlier, after the name of their inventor. They are in four shapes (Figs. 345 to 348), which are alternated in every layer in order to interrupt the joins. Figs. 351 and 352 represent two layers for a single conduit, and Figs. 349 and 350 the two different layers, repeating themselves from top to bottom, for two neighbouring conduits.

Cornices. Dressing with Bricks of Different Colours. Balustrades. — Ordinary bricks, by means of special dressing,

Fig. 353. Fig. 354. Fig. 355.

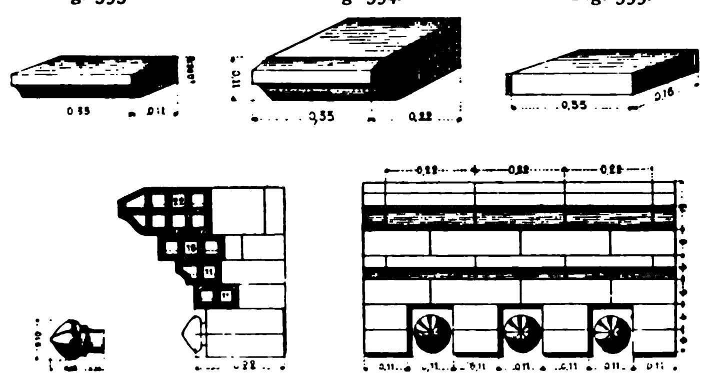


Fig. 356. Fig. 357. Fig. 358.

Figs. 353 to 358.—Hollow Bricks for Cornices.

may be used to decorate cornices, but, unless the bricks are cut, the effects are necessarily limited to straight lines. It is better to use solid, or preferably hollow, moulded bricks (Figs. 353 to 355), because they are less liable to lose shape in drying.

The section (Fig. 357) and elevation (Fig. 358) represent an application of the three types above described, ornamented with knobs (Fig. 356).

The differences in the colours of bricks are made use of in the decoration of cornices, openings, and walls, by arranging them in the most varied patterns, some examples of which are

shown in Figs. 359 to 364. The resources offered by brickwork for decorative purposes were well exemplified at the

Fig. 359. Fig. 360. Fig. 361.

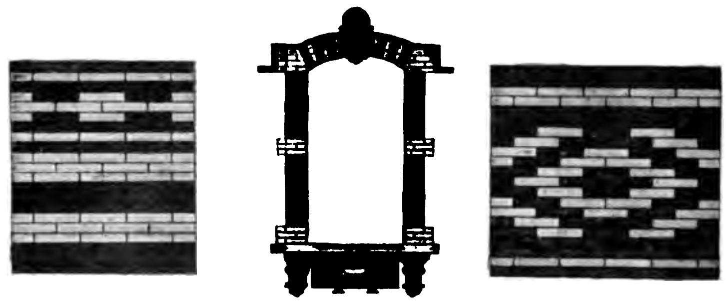


Fig. 362. Fig. 363. Fig. 364.

Figs. 359 to 364.—Various Dressings with White and Red Bricks.

Exhibition of 1889, in the machine gallery, in the pavilion of the Minister of Public Works, and in many other constructions.

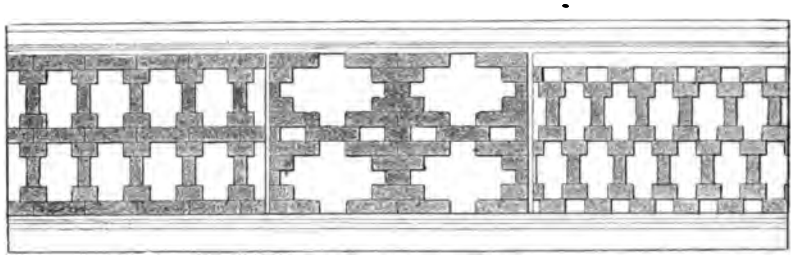


Fig. 365. Fig. 366. Fig. 367.

Figs. 365 to 367.—Open-work Walls for Balustrades.

If to the natural colours, which are necessarily limited, we add the gamut of the artificial tints, the variety of effects is increased.

By combining bricks in different ways, and by using them alone or with stone, we can get an infinite number of styles of dressing, which may be used for open-work walls in their varied applications: window supports, string-courses, balustrades, etc. (Figs. 365 to 367).

CHAPTER IV.

TILES.

§ 1. HISTORY.

THE use of those plates of baked clay which we call *tiles*, is nearly as ancient as that of bricks, but, on account of the state of ruin of the ancient buildings belonging to civilisations before the Roman period, it is difficult to ascertain what kind of roofing covered them. On the other hand, all the necessary materials exist for observing the manner in which the Romans used their tiles, fragments of them being found wherever Roman dominion extended.

They used two kinds of tile. Some rectangular and flat, and furnished with flanges, were 12 to 15 inches long and 8 to 10 inches broad: these were called *tegulæ*; the others, called *imbrices*, were semi-cylindrical in shape. The tegulæ were fixed on the roof by means of notches in the flanges which were placed in the direction of the slope of the roof; the imbrices covered these flanges and were held at their lower extremity by a larger tile (antefix) which was fixed to the cornice and had one end generally decorated.

The Latin buildings were covered with tiles of Roman shape, but generally defective, except in Italy, where they were well made.

Turkish architecture also made use of tiles, which were most frequently enamelled in various colours to match the other building materials.

Up to the 11th century the Roman roofing with its flat rectangular tiles and curved covers was still preserved in the south of France, but after that period the trapezoid shape was substituted for the rectangular.

In the north, Roman tiles had been given up as offering too much hold to rain and wind, and had been replaced by flat tiles furnished at the top with a flange which attached them to the laths. Roman buildings which were roofed with tiles generally had their ridge-pieces decorated with terra-cotta ornaments.

The 13th century saw the introduction of two kinds of tile called "Champagne"; the *ordinary* ones were .35 × .215 metres, were slightly convex in order to give less hold to the wind, and were furnished with a hook, instead of a flange, to fasten them to the laths, and with a hole by which they could be nailed to the rafters, these latter being placed at distances apart equal to the width of the tile. The second kind, called *Comte Henri*, were of smaller dimensions than the others, but were still better finished and usually enamelled on the uncovered part. We may mention, among important roofings executed with these tiles, the cathedral at Troyes, the chapel of the Abbey of Saint-Denis, the château of Beauté-sur-Marne, etc.

In Nivernais and Poitou, tiles in the shape of shells were manufactured at that period, .50 × .165 in dimensions, and having three flutings to carry away the water.

The ∽-shaped tiles, called *Flemish tiles*, still used at the present day, date from the 15th century, and were generally used at that time.

In the south, the flat Roman tile had been abandoned, and the roofing was done entirely with curved tiles, the channel tiles being simply cover-tiles turned upside down; it was the Flemish tile, but in two parts. This system of roofing still remains in the whole of the south of France as far as the Vendée.

The ridges were covered with ornamented tiles usually varnished; at the ends were placed spikes which were sometimes real monuments, especially in the 14th century.

From the 15th to the beginning of the 19th century, the tile industry in France made no improvement; on the contrary, the tiles during this period were roughly fashioned and poorly baked. In 1851 the invention was made which revolu-

tionised tile-making, and raised it to that pitch of perfection at which it stands to-day. We refer to the invention of machine-made fitting tiles; this was a French invention due to the brothers Gilardoni of Altkirch in Alsace.

Up to that time tiles had only been made by hand, and the introduction of machinery for their manufacture brought with it rapid improvements which considerably extended the use of these products for the roofing of buildings. If many flat, hollow, or Flemish tiles are still made, it is almost entirely for maintaining existing roofs.

§ 2. MANUFACTURE.

(1) Moulding.

Hand-moulding.

The preparation and choice of the clay for the manufacture of tiles should be performed with even more care than for that of bricks. The clay should have been weathered, should be sufficiently rich to prevent the tile from being too porous, and should be well separated.

The moulding has no special features; it is done with thin moulds having a notch on one side, and resting on movable

Fig. 368.

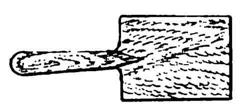


Fig. 369.

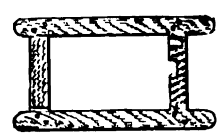


Fig. 370.

Fig. 368.—"Planchette." Fig. 369.—Mould for Flat Tile.
Fig. 370.—Mandrel for making Curved Tiles.

"planchettes" (Fig. 368). For the demoulding is done on the table itself by raising the mould when the excess of clay has

been removed with the "plane." The boy takes away the "planchette," and on his way forms the hook by raising with his thumb the small portion of clay moulded by the notch, then he deposits the tiles side by side on a well-levelled and sometimes paved space. When the clay has attained a sufficient degree of consistency, it is taken to the drying-rooms, and after it has become firm enough it is stamped and curved; this is done with a wooden beater, the workman being seated on a bench in front of the tiles. The seams having been cut off and the edges dressed, the tiles are placed in the drying-sheds to complete their desiccation, which takes from a week to a fortnight according to atmospheric conditions. Curved tiles are made by bending the flat slab over a mandrel of suitable shape.

A large number of special tiles, such as ornamented ridge-tiles, end-pieces, finial-pieces, etc., which are used with machine-made tiles, are also made by hand in plaster moulds of the desired shape.

Machine-moulding of Tiles.

The mechanical moulding of tiles comprises three operations: (1) the preparation of the clay; (2) the formation of slabs or regular plates of clay, the dimensions of which depend upon those of the tiles; and (3) the transformation of these slabs into tiles by stamping with plaster or cast-iron moulds of the required shape.

1. **Preparation of the Clay.**—This is carried out in the same way as for bricks, but requires more attention. The choice of clay is very important, and thin clays no longer being suitable alone, there must be added to them a certain quantity of rich clay which gives to the paste the degree of cohesiveness and tenacity necessary to ensure for the tiles their essential qualities, especially *imperviousness* and *resistance*. The paste, thus rendered as homogeneous and ductile as possible, should be free from all impurities.

Here an important question presents itself: What quantity of water should a paste contain to make the best tiles?

Pastes are placed in three classes according to the quantity of water contained in them and evaporated at 100° C.

Soft	pastes containing	20 to 25	per cent.
Firm	,, ,,	15 to 20	,,
Hard	,, ,,	10 to 15	,,

that is to say, not much more than the amount naturally contained in clays.

Each kind of paste requires a different method of manufacture, possessing advantages and disadvantages of its own.

Soft Clay.—The clay blended in this manner acquires the maximum of ductility and homogeneousness which can be expected from its plasticity. The separation of the paste into thin laminæ, which slide over one another, as is always observed when it is expressed from the die, will be reduced to a minimum. Besides, the passing of the *soft* slab under the press will perfectly weld together the molecules which might become separated, and a good firing will give as a final result a product with a good ring, a clean fracture, and fine grain, signs of excellent quality.

The drawbacks of soft paste for manufacturing purposes are: difficulty of handling slabs and tiles of no consistency; the adhesiveness of the paste renders the use of cast-iron for moulding impracticable, and recourse must be had to plaster moulds, the quick wearing out of which necessitates frequent renewal; as we work with soft paste a strong pressure cannot be used, and this diminishes the clearness of reproduction of the details of the mould, for tiles are not stamped like bricks; finally, the large quantity of water contained in the paste lengthens the time of drying,—hence an increase in the dimensions of the drying-sheds,—and its removal causes hollows—hence the products are more porous.

All being considered, the production with soft paste is small, and the cost somewhat high.

Firm or Semi-hard Paste.—The quantity of water being reduced, the paste is more easily handled than the preceding kind; it can support a greater pressure, and can be moulded in cast-iron, which gives the tiles very clean-cut faces, a great delicacy of shape, and sharp edges. The drying is quicker and the porosity not so great.

The inconvenience of this method, which largely counterbalances its advantages, is that it requires more powerful machinery and in consequence absorbs more motive force.

Hard Paste.—In this process, the clay is taken almost as it comes from the pit, or, if it is too dry, a certain amount of water is added to it, not exceeding 10 to 15 per cent. Under these conditions blending becomes difficult, and requires powerful machines absorbing much motive force. Another grave disadvantage is the exfoliation of the paste as it passes through the die. With soft clay this is insignificant, but with hard paste it becomes very pronounced, and the slabs are formed of laminæ placed one over the other like the leaves of a book. The slight exfoliation of soft or firm paste disappears in the press, thanks to the plasticity given to the clay by the water; with hard clay, considerable and repeated pressure is necessary to produce the same effect, and the action must also be completed by a strong firing, which will weld together all the parts of the tile.

If the pressure or the firing is insufficient, the laminated hollows in the clay will retain the water and the frost will chip the tiles, which in a very few years will be useless.

In this respect, then, manufacture with hard paste is more delicate than the previous methods, but by a judicious choice of clays, a suitable blending, and a strong firing, it gives good hard products, not very porous, and of clean-cut shape.

In spite of these qualities, however, the products have been much decried on account of certain accidents which we must explain. When tiles made of hard paste first made their appearance, their success, thanks to their beauty of shape and bright colour, was very great; and, as the moulding of them was somewhat cheaper than that of those made of soft clay, a large number of factories laid down plant for this method of manufacture. But, as often happens, too much advantage was soon taken of this economy; tiles were made without careful choice of clays, without proper preparation, and without sufficient firing, either to economise fuel, or because the clay used would not bear a great heat. The outer appearance did not suffer; on the contrary, the slight degree of baking of the products gave them

a fine and uniform red colour, which made them extremely fashionable. Architects and engineers — and this is how they unconsciously helped to create a current of opinion which led to numerous disappointments—at last only used tiles of uniform tint and very red. But this tint is easily obtained by a slight firing, and therefore well-fired tiles, which are usually of a less agreeable and uniform colour, were partly neglected.

Time showed how wrong it was to forsake the wholesome traditions of good manufacture. When subjected to the weather the tiles at first behaved fairly well. But when their surface, which was not very pervious and strongly compressed, was attacked by the slow action of the water, they were rapidly destroyed, for the numerous hollows left by exfoliation filled with water, and the cold of successive winters caused these badly made tiles to fall into dust.

The reaction was all the more violent because lawsuits followed, and materials which had proved their utility for thirty or forty centuries were very nearly abandoned for roofing purposes! But the manufacturers with soft clay, between whom and those working with hard clay there was keen competition, skilfully took advantage of these circumstances and made hard-clay manufacture responsible for them; and in this they were not entirely wrong. In 1879 there appeared a pamphlet (*La Tuile mécanique*, by L. Laubière, roofing contractor), in which, side by side with some excellent observations, other too extreme conclusions were stated. Acccording to the author, only soft-clay manufacture could give good tiles. Bad results may be obtained from soft clay just as much as from hard clay, and good tiles may be made with either. But it is certain that manufacture with hard clay is *more difficult*, *more delicate*, and *requires good clays*. Should we make a method responsible because some people apply it badly? Thus hard-clay products require a high degree of firing, and it is evident that if we use clays which cannot bear that firing, through being too fusible, or contracting unevenly and becoming warped, only a bad result can be obtained.

It is just the same if we work with soft paste made of poor clays, although the defects may be less pronounced. Soft paste,

firm paste, and hard paste all may give good tiles, but clays cannot be used indiscriminately in any one of these processes, and it is prudent to diminish the disadvantages of hard paste by slightly increasing the quantity of water; it will then be in a better condition for working.

As for the consumer, his interests may be safeguarded, without inquiry as to the method by which the tiles are made, if he deals with *solvent and well-known firms*, and asks them for a warranty of ten years against rain and frost: this would never be refused by conscientious manufacturers who are sure of the quality of their goods.

The preparation of clays is performed with the same machines as for bricks; for firm pastes, however, special pug-mills (Fig. 65) or perforated cylinders (Fig. 82) are used

2. **Preparation of the Slabs.**—When we work on soft or firm pastes, we use the screw or propelling roller machines described on pp. 114 and 123, with a modified die. For hard pastes we must have recourse to the piston machines called "galettières." Fig. 371 represents a machine of this kind in which two pistons compress the clay alternately in two boxes, having the dies in one face.

M. Dumont, one of the promoters of hard-paste manufacture, has invented a double "galettière" (Figs. 372 to 375), composed of a cast-iron frame supporting two compression boxes in which move two pistons worked by two cranks fixed to the same extremity of a vertical shaft, the lower end of which has a large toothed wheel driven by a small pinion. All this gear is hidden in such a way that there is no danger in approaching the machine—a very important advantage.

The dies are of conical section, and metallic plates, whose distance can be regulated by small screws, allow of the section of the issuing orifice being altered to suit requirements, or compensate for wearing away.

The clay, having been passed between granulating cylinders, or pugged, is thrown on to a sheet-iron plate, which is pierced with two openings corresponding to those of the compression boxes. When one of the pistons has done its work and returns,

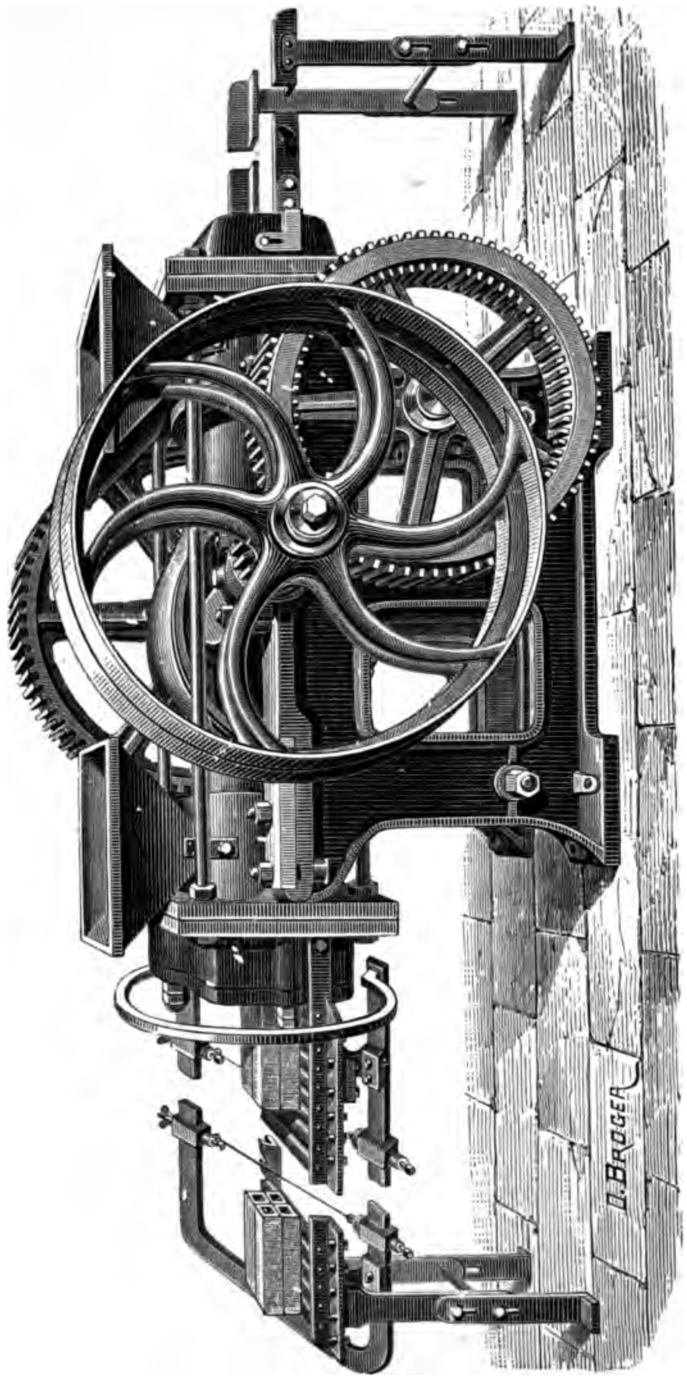


Fig. 371.—Double-action "Galettière" (Boulet).

it uncovers the orifice of the box, and the clay at once falls into it; the piston continuing its motion compresses the clay and drives it out in the form of a continuous slab, which passes between two rollers held by flanged springs. The lower roller, called the *greaser*, dips into a little reservoir of oil, and in its rotation lubricates the bottom of the slab. The upper roller, called the *cutter*, carries one or several blades, the distance of which, measured on the circumference, is equal to the length of a tile. In turning, these blades come in contact with the slab and cut it into the required lengths.

Fig. 372.

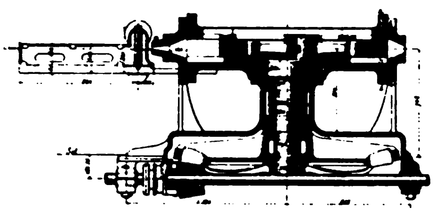


Fig. 373.

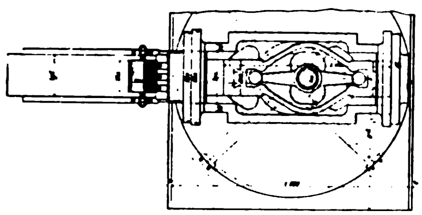


Fig. 374.

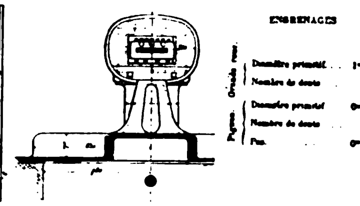


Fig. 375.

Figs. 372 to 375.—Double-action "Galettière" (Dumont).

The slabs thus cut are firm enough to be carried in the hand without losing their shape; a boy takes them, and places them in piles on a waggon which carries them to the presses. During this handling, the oil on the bottom of each slab is partly deposited on the top of the one below, and thus both faces become lubricated for stamping.

The advantages of this "galettière" are: its small volume, its hidden mechanism, the use of one hopper for the two boxes, automatic cutting and greasing.

3. **Transformation of the Slabs into Tiles—Flat Tiles.**—The manufacture of these tiles by hand is rather slow and con-

sequently troublesome; therefore, in factories with steam-power it is better to use machinery.

The expression of the clay is performed by a machine of some kind furnished with a suitable die. The transformation of the slab into tiles is effected in various ways. The Joly cutting-table (Figs. 376, 377) is provided with two rollers; the lower one has a projection corresponding to a hollow in the upper one, and the latter has blades fixed longitudinally upon it. When the slab passes between these rollers, it makes them revolve; the projection on the lower roller presses down the paste at regular

CUTTING-TABLE FOR FLAT TILES (Joly).

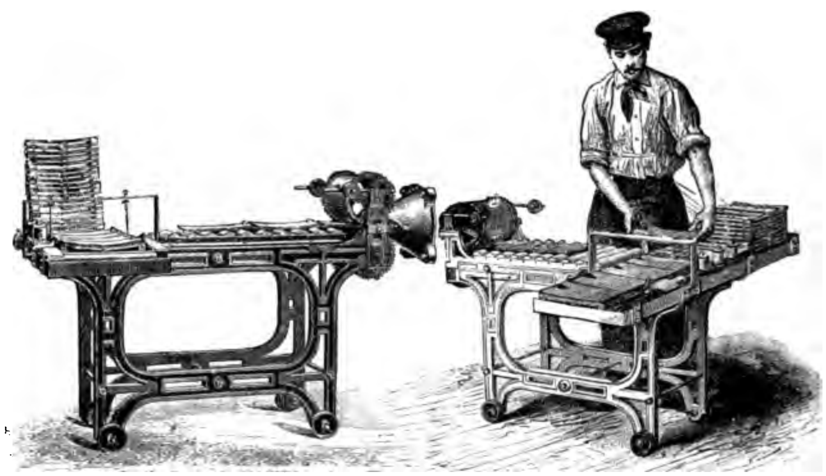


Fig. 376.—Front View. Fig. 377.—Side View.

intervals, thus forming the hook, while the blade cuts the tile to the required length (Fig. 376). The workman has only to take up the tiles and place them on boards (Fig. 377) to be scraped; then they are carried to the drying-sheds. A cutting-table of this kind produces from 1200 to 1600 finished tiles per hour.

Another method, suited to thick tiles, requires a somewhat different die: the prism of clay comes out with a projection in the middle, of the same section as the required hook. The die is arranged either for one tile (Fig. 378), two side by side (Fig. 379), two, one over the other (Fig. 380), or four tiles (Fig. 381).

The special cutting-table (Fig. 382) cuts the prism into slabs of the required length, and, at the same time, another horizontal

Fig. 378.

Fig. 379.

Fig. 380.

Fig. 381.

Figs. 378 to 381.—Dies for Hooked Flat Tiles.

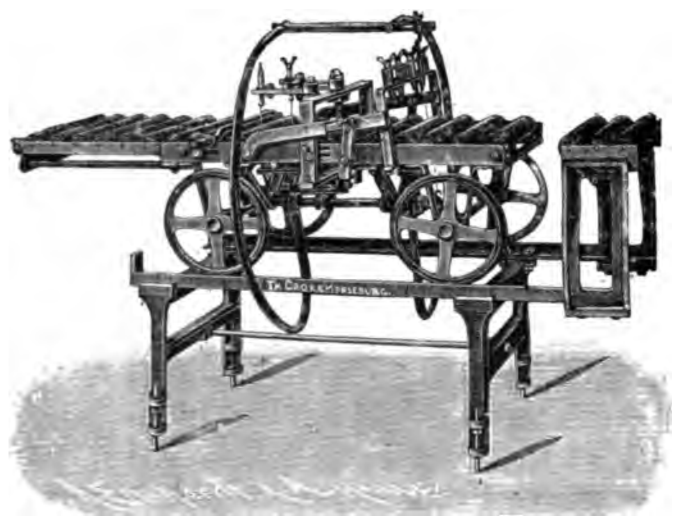


Fig. 382.—Cutting-table for Hooked Flat Tiles.

wire takes off the projecting rib at the surface, leaving a small part which is to form the hook.

When two tiles come out one over the other, the rollers of the cutting-table have a notch in the middle which allows the lower rib to pass, and there are two horizontal wires to remove the ribs.

Fitting Tiles.—These tiles are of different shapes, but are all manufactured in the same manner, by stamping between two plaster or metal moulds of the desired form. A great number of mechanical methods of producing the necessary pressure may be devised; the simplest is the screw press. Cams and levers have

Fig. 383.—Screw Press, worked by Hand (Jäger).

also been used, and for large production the presses called "revolver" are utilised.

There are three classes of machines—

A. SCREW PRESSES: (1) *Worked by hand*; (2) *by steam*.

B. CAM AND JOINTED LEVER PRESSES.

C. REVOLVER PRESSES.

A. SCREW PRESSES.—(1) *Worked by Hand*.—The mechanism of these presses is well known. A large flywheel turns a screw, which has at its lower end one side of the mould; the other part of the mould slides upon a cylindrical iron rod; in order to fill it, the

workman draws it towards him, and, holding it horizontal by means of a handle, places the slab of clay into it, and then pushes it back under the screw, where it is held by catches exactly under the upper part. The flywheel is set in motion, and the stamping takes place; but two or three compressions should be made in order to force the clay into all the cavities of the mould, and to ensure that all the bubbles of air, which the shock accumulates in the lower part

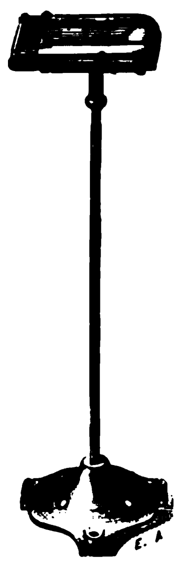


Fig. 384.—Swivel Stand for trimming Tiles (Boulet).

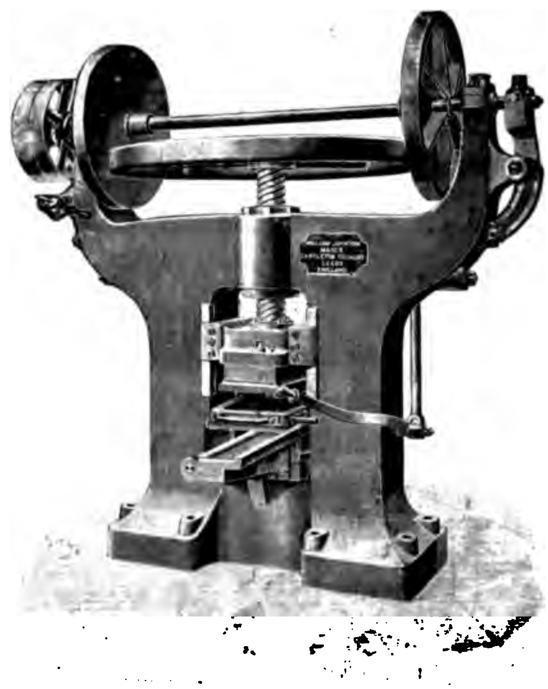


Fig. 385.—Screw Press, worked by Steam (Johnson).

of the tile, may be driven out. As there are two moulds, while one is under pressure the other is being filled, and will be ready to take the place of the first as soon as the compression is over. The demoulding is done by turning the bottom of the mould round its supporting rod, and receiving the tile on a board. However well-fitting the moulds may be, the compression always leaves seams, and to remove these, the board and its tile is placed on a swivel stand (Fig. 384), and they are taken off by means of a stretched wire, the tiles being afterwards taken to the drying-sheds.

For a large output, this stand is replaced by a circular revolving table, in front of which women are seated.

The tiles come to the presses on an endless band, then pass

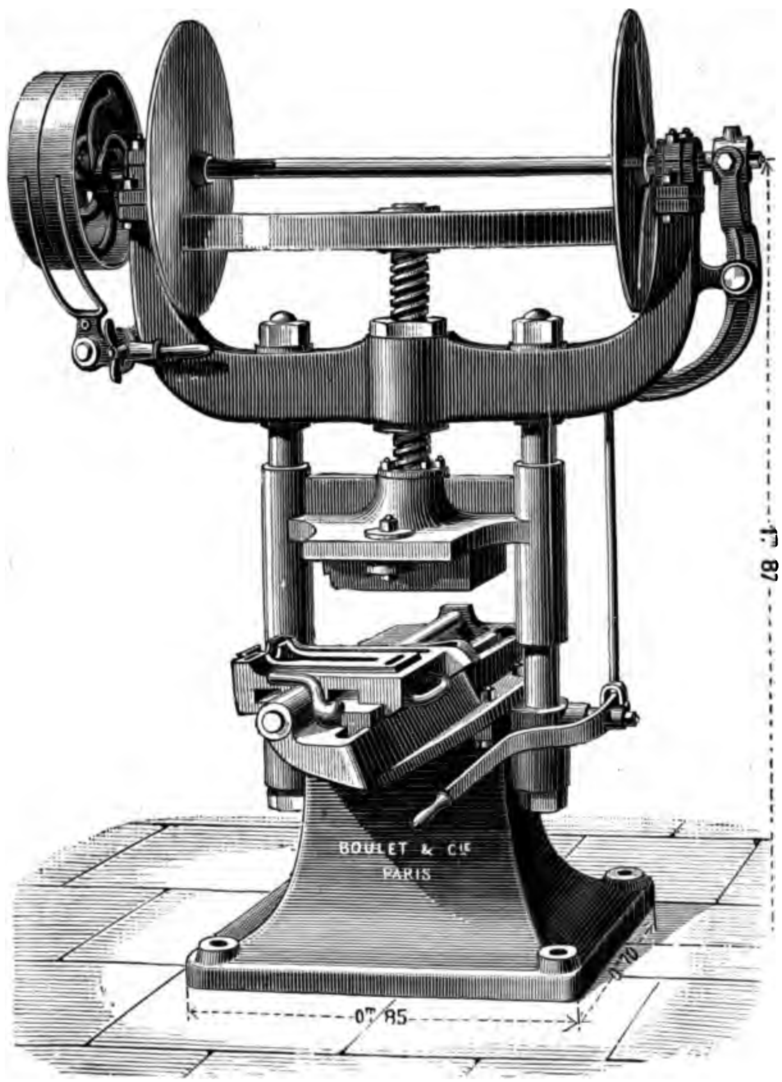


Fig. 386.—Screw Press, worked by Steam (Boulet).

to the trimmers, and afterwards proceed to the drying-sheds by another endless band.

With hand-presses about 150 tiles an hour can be made, giving three compressions to each.

(2) *Worked by Steam.*—In these presses (Figs. 385, 386) the upper part of the screw is furnished with a flywheel which, by means of friction discs, can be turned in either direction. A lever placed within reach of the workman's hand allows him to move the screw in the direction required. Another gearing, placed well in sight, acts upon the belting, and is used to stop the shaft on which the discs revolve.

These presses have plaster moulds, and are only suitable for working on soft or semi-firm paste; their output is about 250 to 300 tiles per hour.

B. CAM PRESSES.—These consist of a solid shaft furnished

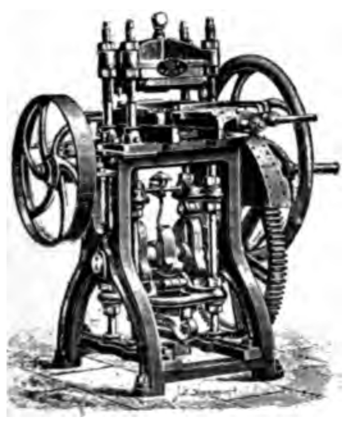


Fig. 387.—Cam Press with Triple Compression (Joly).

Fig. 388.—Press with Crank and Handle (Chavassieux).

with two cams with three hollows and three projections, and set in motion by gearing worked by hand or steam. Each hollow in the cam corresponds to a pressure of the upper plate upon the slab of clay, and is immediately followed by a partial demoulding caused by the projections; every turn of the shaft then produces three compressions, followed by three demouldings; and in consequence of the shape of the cams, the compressing force increases from the first to the third, being on an average 60 kilog. per square metre.

Demoulding is effected by turning the movable carrier on which the mould rests round the bar supporting it, and the tile

is received on a board. The carrier carries two moulds, so that one can be filled while the other is being pressed.

The Chavassieux press (Fig. 388), also worked by hand, has only one mould-carrier; the motion is transmitted to the upper mould by means of a crank and winch.

In the press represented by Fig. 389, the upper mould is moved by jointed levers. It is worked by power, and stops automatically when the tile is sufficiently compressed. It cannot

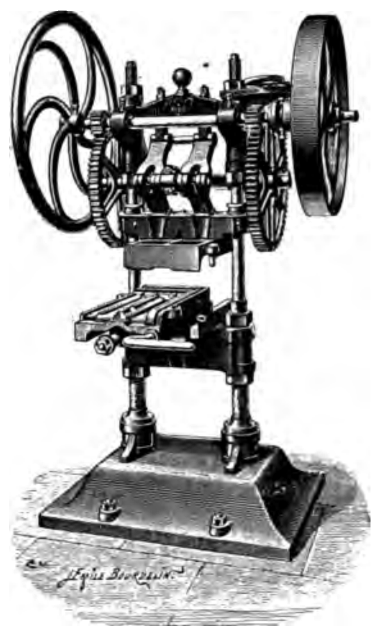


Fig. 389.—Crank Press for Tiles (Joly).

be started unless the mould is exactly in its place. Its production is about 200 to 300 tiles per hour.

C. REVOLVER PRESSES.—The invention of what are called mechanical tiles led to that of machines allowing of a large output.

The problem was also solved by Gilardoni, who, by means of some hints given to Jean Schmerber (1824–1895), a partner in the firm of Schmerber Brothers of Tagolsheim (Upper Rhine), suggested to him the idea of the press which bears his name, and of which the present presses are only variations.

This type of press (Figs. 390, 391, 392) consists of a shaft C geared to another shaft A, which carries the driving pulleys and two flywheels, B B. On the shaft A is fixed a steel

FIVE-SIDED TILE PRESS (Schmerber System).

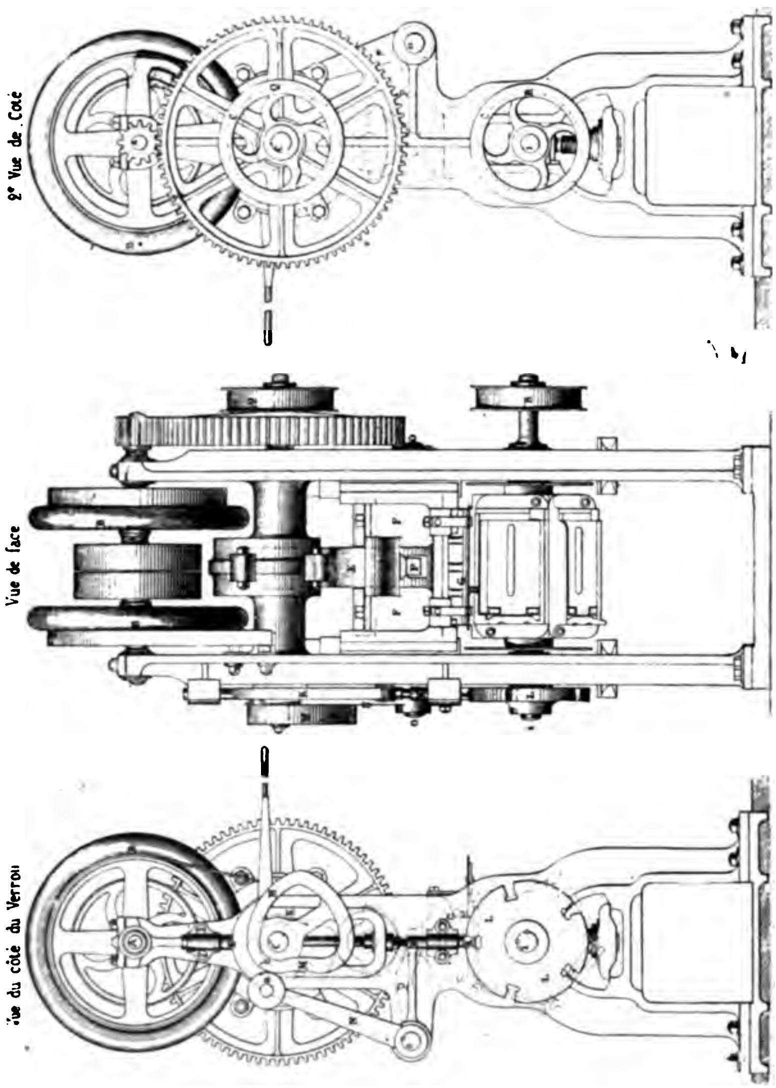


Fig. 392.—Side View.

Fig. 391.—Front View.

Fig. 390.—View from the Bolt Side.

eccentric D, which acts on a slide E, also of steel, and placed in the mould-carrier F, which holds the upper mould G.

Below is another mould-carrier with five sides mounted on a shaft I, which is furnished at one end with a plate with five

notches L, and at the other with a grooved pulley R. The plate L is kept fixed by a bolt K, which slips into the notches.

While the counter-mould G compresses the clay on the mould H, a workman placed behind the machine puts on a board the tile just pressed, and a second workman in front of the press places on one of the sides of the revolving carrier the slab of clay for the next tile. When the compression is finished, the mould-carrier F is raised by the arm P of a jointed lever, which is fixed to the shaft O, and the second arm N of which is set in motion by the eccentric M acting on the slide *a*.

When this movement is nearly completed, a little cam *b* comes to unlatch the bolt K, and at this moment the belt joining the two pulleys Q and R is stretched by means of a projection on the pulley Q, so that the shaft I begins to move, and continues until the bolt K, released by the cam *b*, falls back into a notch of the plate L. The lower mould-carrier has then described one-fifth of a circle, and another mould is now below the counter-mould G. The cam D, by means of the slide E, again acts upon the mould-carrier F, the descent of which becomes slower as the pressure increases, in order to allow the air and the excess of clay to escape from between the two moulds.

The work may be done with soft, firm, or hard clay according as the moulds are of plaster or cast-iron.

The shaft I rests, by means of a regulating screw *d* (Fig. 392), on safety plates which protect the supports in case of an accidental excessive pressure. A break acting on the felly of one of the flywheels allows of the machine being instantaneously stopped.

The tiles are carried to the drying-sheds after being trimmed; the output is from 400 to 450 tiles per hour.

In the Boulet machine (Fig. 393) the principal parts are the same as in the foregoing machine, and its working is similar. The moulds are of plaster or cast-iron, according to the method of manufacture.

The Jäger machine (Fig. 394) has no belt for moving the revolving mould-carrier, but the latter is provided with a wheel

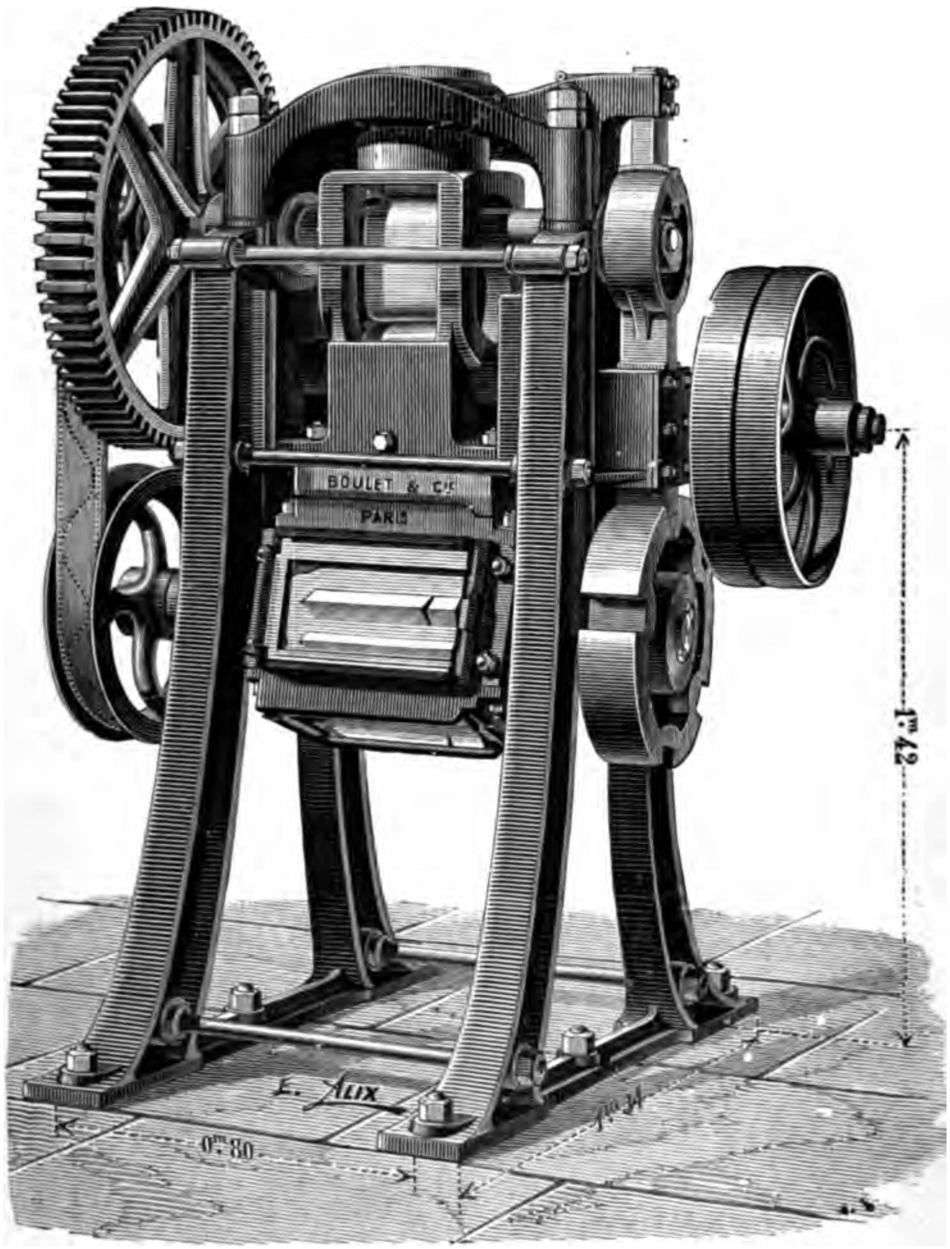


Fig. 393.—Five-sided Tile Press (Boulet).

with curved segments which rub against a felly fixed to the large gear-wheel. This felly is interrupted for a certain distance, and in the hollow is a little rod perpendicular to the wheel, which, at a certain moment, enters a notch in the segmented wheel and drives it forward one-fifth of a revolution. The rod

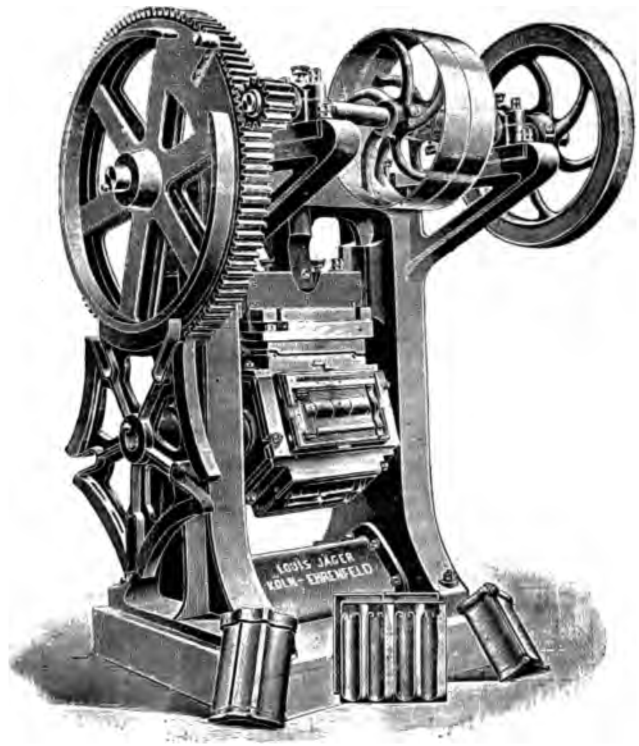


Fig. 394.—Five-sided Tile Press (Jäger).

then frees itself, and the felly, rubbing against the segment, keeps it in its position.

A similar arrangement is found in the Groke (Fig. 395) and Laeis (Fig. 396) machines. The former is fitted with a break for instantaneous stopping as in the Schmerber machine.

In the Lobin press (Fig. 397), the motion is communicated to the counter-mould by means of knee-piece cranks, and the intermittent rotation of the revolving mould-carrier is effected by a ratchet-work moved by jointed levers of which one end is drawn on by a rotatory motion. In this machine, as in the

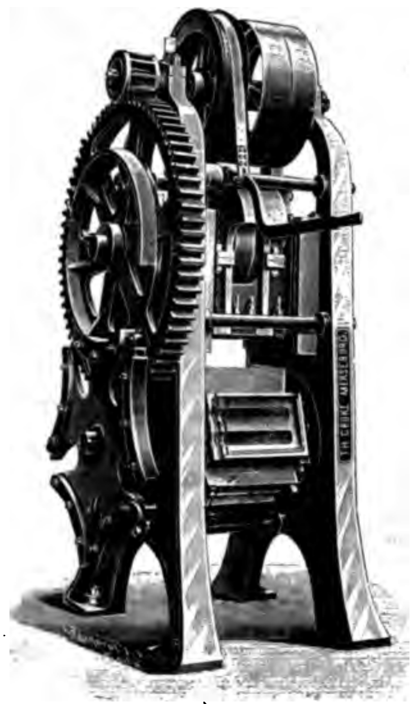


Fig. 395.—Five-sided Tile Press (Groke).

Fig. 396.—Five-sided Tile Press (Laeis et Cie.).

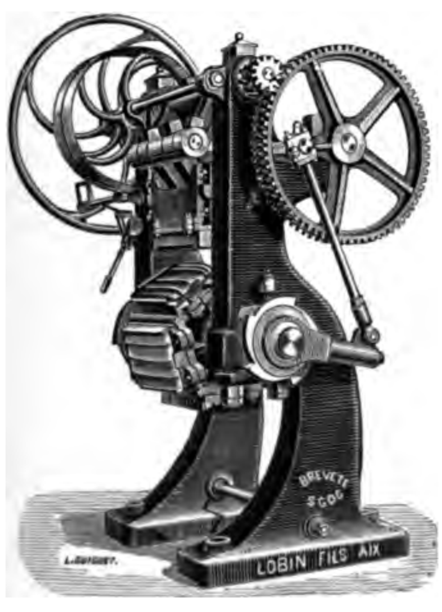


Fig. 397.—Five-sided Tile Press (Lobin).

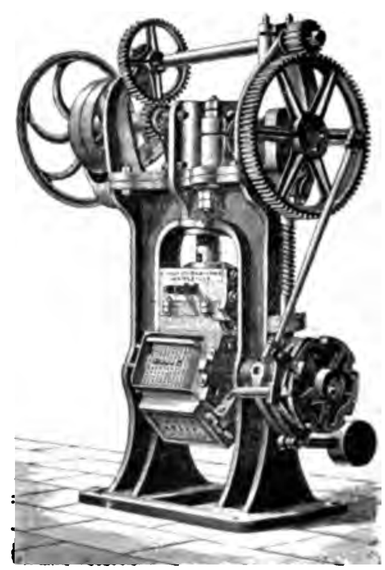


Fig. 398.—Five-sided Tile Press (Chavassieux).

preceding ones, the movement of the counter-mould is slackened at the end of its course, and there is besides a double compression, as in the Joly machines.

The Chavassieux press (Fig. 398) possesses a similar mechanism to the last for turning the revolving mould-carrier, but the counter-mould is moved by an eccentric.

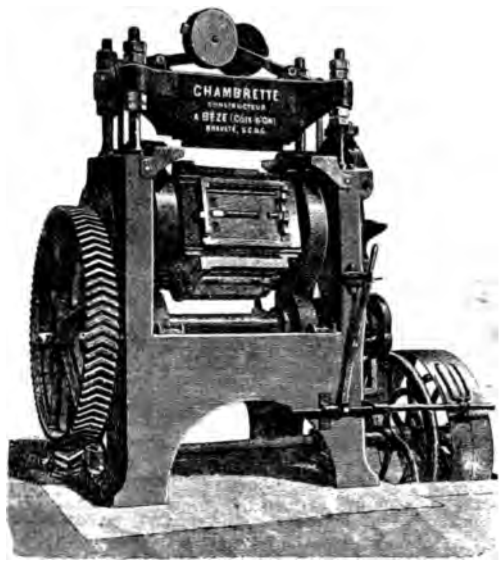


Fig. 399.—Revolver Press (Chambrette Belon).

The Chambrette-Belon press (Fig. 399) has this special feature, that the upper part is fixed and it is the revolving mould-carrier which is movable. The motion is effected by cams which cause successive compressions.

Moulds.

When the tiles are made of soft clay, the moulds of the presses are of plaster. The pressure and damp soon destroy them, especially the upper ones which transmit the pressure, therefore spare ones should always be at hand.

The plant necessary for making plaster moulds is as follows: (1) two matrices of chased and polished cast-iron, one representing

the lower part (Fig. 403), the other the upper part (Fig. 404) of the tile; (2) two cast-iron frames (Figs. 400, 402) which are to receive the plaster moulds and are fixed by bolts to the mould-carriers of the presses; (3) an oak table (Fig. 401) provided with iron ribs, and a screw which passes through a bronze nut fixed in an iron arch.

Each matrix, having been well greased with black soap or resin oil, receives the plaster (of Paris), which is poured in in a fairly liquid condition, without, however, being too soft; it is then covered with one of the cast-iron frames, and carried to the table, where it is held tightly pressed down by the screw

MATRICES, FRAMES, AND TABLE FOR MAKING PLASTER MOULDS.

Fig. 400. Fig. 401. Fig. 402.

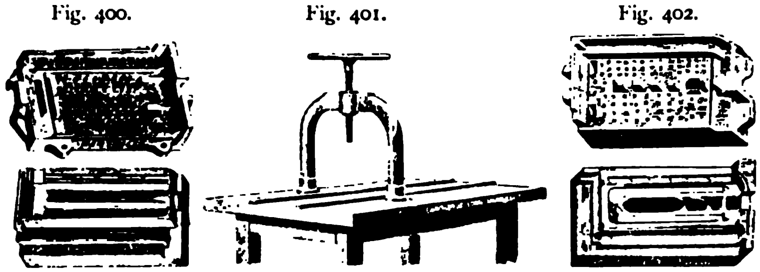


Fig. 403. Fig. 404.

Fig. 400.—Frame to receive the Upper Mould. Fig. 401.—Table on which the Moulds are pressed. Fig. 402.—Frame to receive the Lower Mould. Fig. 403.—Matrix of the Bottom of the Tile. Fig. 404.—Matrix of the Top of the Tile.

until the plaster has become hard. The matrix is now removed, and the plaster mould remains fixed in the cast-iron frames. The frames thus prepared are then attached, those containing the upper part of the tile to the upper mould-carrier, and those containing the lower part to the press supports (Figs. 383 to 389) or the revolving mould-carrier (Figs. 390 to 399).

To make sure of a continuous supply, there should be a pair of matrices (Figs. 403, 404) for every five presses, and for each press, seven upper frames (Fig. 400) and four lower frames (Fig. 402), which makes five bottoms and one top in use; two bottoms and three tops being used in remaking the plaster moulds. For carrier-presses, we must have, besides the two

matrices, two or three pairs of moulds according as the carrier is single or double.

When we are working on hard clay, the plaster moulds of small resistance are replaced by cast-iron moulds, which are lubricated for each tile to prevent the clay from adhering to the metal.

In either method each kind of tile requires special matrices as well as, in the case of plaster moulds, cast-iron frames.

Curved Tiles.—The Dutch ∽-shaped face is obtained by a die of the required section, and the curved slab, as it comes from

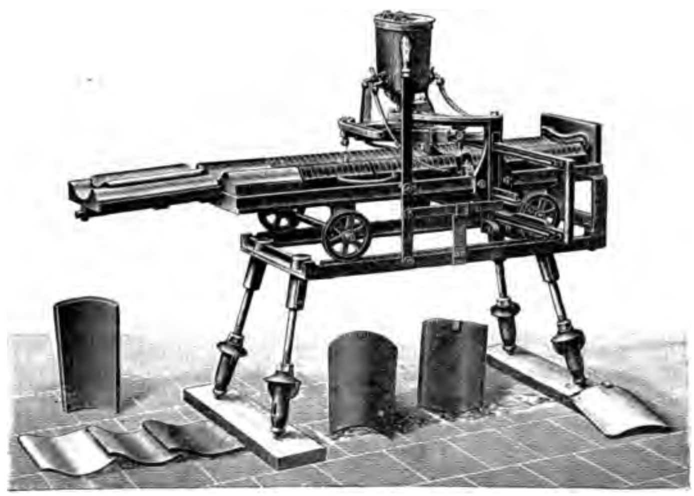


Fig. 405.—Cutting Machine for Curved Tiles (Schlickeysen).

the machine, slides over a mandrel which is lubricated by a current of water (Fig. 405), and is there cut into suitable lengths, while a fixed wire divides it into two parts, its breadth being double that of the tile.

By increasing the curvature of the die we obtain the shape of the semi-cylindrical Roman tiles. As they are conical, we place them, when they come from the mandrel cutter, on another conical mandrel shaped like the tile, and with an iron wire we take off the parts which project on each side (Fig. 370). The tile then is of the required shape (Fig. 405, to the left).

Another process, less economical, however, consists in express-

PARTICULARS OF TILE PRESSES.

Maker.	Number.	Pulleys. Dimensions in Metres.	Pulleys. Number of Turns.	Weight.	Horse-power.	Output per Hour.	Price in Francs. Without Moulds.	Price in Francs. Complete with Moulds, but without Matrices.	Remarks.
HAND AND LEVER PRESSES.									
Chavassieux (Fig. 388)	...	...	...	1725	...	150–180	**2000**	**2300**	Single carrier.
	...	...	...	2100	$\frac{1}{2}$	300–350	**2520**	**3150**	Two carriers.
Joly (Fig. 387)	2	...	...	1300	$\frac{1}{4}$	...	**1700**	**1800**	Extra moulds cost from 100 to 150 fr.
Joly (Fig. 389)	1	...	...	1800	$\frac{3}{4}$	...	**2100**	**2200**	
	...	.67–.08	...	1000	$\frac{1}{2}$	200–250	**1400**	**1500**	Crank press.
Laeis et Cie.	*a*	...	...	620	...	150	**700**	**1200**	
	b	...	...	1250	...	170	**1200**	**1700**	
SCREW PRESSES WORKED BY STEAM.									
Boulet (Fig. 386)	small	.5–.08	130–150	1500	1	250–300	...	...	
	large	.5–.08	130–150	3000	1	300–400	...	...	
Johnson (Fig. 385)	...	...	...	...	...	...	...	...	
Laeis et Cie.	...	...	...	2500	1.5	200	**2400**	**3000**	
REVOLVER PRESSES.									
Boulet (Fig. 393)	...	.75–.11	215	5500	1	500	...	...	
Chamb. Belon (Fig. 399)	...	...	...	...	...	...	...	...	
Chavassieux (Fig. 398)	...	...	...	4900	1	500–600	**4400**	**5500**	
Jäger (Fig. 394)	...	...	...	5000	1–2	400–500	**2750**	**3500**	
Groke (Fig. 395)	...	...	...	3800	...	400–500	**3750**	**4100**	Reduction of 25 per cent. on these prices.
Laeis et Cie. (Fig. 396)	...	...	65	3150	3	...	**2850**	**3450**	
Lobin (Fig. 397)	...	1–.15	60	4000	1–2	500–600	**3850**	**4500**	Cam and knee-piece types, gradually reduced pressure.

ing the paste in the shape of a half-cylinder bounded by a flat surface, thus having the appearance of a gas retort. An iron wire cuts off the flat part A B (Fig. 370), which is thrown under the machine, and the curved part is taken to a mandrel and shaped conically as above.

The fitting ridge-tiles of the usual shape are made with screw or cam presses. As for those of complicated form or limited consumption, it is advisable, as matrices are very expensive, to make them by hand with plaster moulds of the desired shape, the moulds being constructed with the aid of models.

(2) **Drying.**

As in the case of bricks, open-air drying-places may be either on the ground, or in storeys. The former are only possible for small installations which make mainly flat tiles. They are mere sheds like those used for bricks, but they must, on account of the shape of the tiles, be fitted with open shelves of suitable dimensions.

So-called mechanical tiles, which are made of soft or semi-firm paste, are received as they come from the press on small frames ("planchettes") (Fig. 406) slightly larger than the tiles. In order not to have several kinds, their dimensions are fixed at: .45 by .25; the laths being .04 to .05 wide and .01 thick; this being so they can be used for any products. To avoid waste they must be well made.

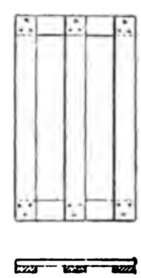


Fig. 406.—"Planchette" for Tiles.

After trimming, the frames with the tiles on them are placed on the shelves of the drying-sheds. In constructing these shelves we must take into consideration the space at disposal and the dimensions of the tiles; they are constructed economically and so as to take up as little room as possible, leaving the space strictly necessary for moving about.

When the drying-places are on the ground-floor, the frames

are placed on special barrows with shelves (Fig. 408) to be taken to the drying-shelves; if the tiles are too high to be put on these

Fig. 407.—Platform Barrow.

Fig. 408.—Shelved Barrow for Tiles.

barrows, platform barrows are used like those serving for bricks (Fig. 407).

Fig. 409.—Shelved Drying Waggons.

Tiles made of hard clay are firm enough to do without frames. They dry very quickly, hence the empty space in the

shelves is much reduced, and more tiles can be placed in less compass. M. Dumont, one of the originators of this kind of manufacture, only leaves about $2\frac{3}{4}$ inches between the shelves. Each shelf is formed of three strips for tiles of 28 to the square metre, and of four for tiles of 13 to the metre. To move the tiles, a two-pronged wooden fork is used, which is slipped under them and afterwards withdrawn.

M. Dumont also used movable drying-places formed of shelves mounted on wheels. When the weather is fine, these may be left in the open air, and desiccation takes place rapidly; in unsuitable weather, they are placed in a drying gallery, which

Fig. 410.—Tile Barrow.

may, with the limitations already mentioned, be usefully employed for the drying of tiles.

For transporting the products, M. Dumont used a special barrow (Fig. 410), holding twenty large-size tiles on edge, and easily handled among the shelves, thanks to its shape.

Communication between different storeys of the drying-sheds is made by lifts adapted for taking barrows, or by special tile-raisers with swinging trays like that represented in Fig. 187.

Cost of Drying-sheds.—Only two systems of drying are possible for regular manufacture: storeyed drying-places, or closed galleries. The cost of their installation has been calculated (p. 182); but to the first estimate must be added the cost of the

shelves, and also that of the "planchettes" if soft or semi-firm clay is used.

A building like the one shown in Figs. 176 and 177 is sufficient for a daily production of 20,000 to 25,000 tiles from soft clay. For such an output we must estimate the cost, in addition to that of the building, at—

Shelves, about	10,000 fr.
Planchettes at 10 centimes each	4,500
Sundries	500
Total .	15,000 fr.

With hard clay, the same building would serve for double the daily production mentioned.

(3) Firing.

This is carried out in kilns identical with those used for firing bricks, and mainly in continuous kilns, in the case of mechanical tiles. As tiles are of a more fragile nature, they must not come into direct contact with the fuel. A tile-factory nearly always produces bricks also, and in this case they are arranged round the tiles, which are thus protected as if by a sagger. To do this, however, the production of bricks must be one-third or one-half of the products made. When it is less than that proportion, we must try to find a kiln which, while ensuring the continuity of the fire, keeps the tiles out of contact with the fuel. The Virollet continuous kiln, called also "four à tranches," is one of those most commonly used.

Like other continuous kilns, it consists of a certain number of compartments which are reached by doors, but which are separated from one another by walls pierced below with holes (Fig. 412). On the floor of the kiln, a certain number of fire-bars 4 to 6 inches broad are arranged transversely. Under these bars, which occupy the whole width of the kiln, is an empty space into which the outer air is introduced through a conduit in the thickness of the wall and issuing at the level of the pavement. The orifices of these conduits are closed with sand plugs.

The fuel, being thrown through small openings in the roof, falls on the bars and burns there. To preserve the tiles from contact with it, several layers of bricks are placed at the bottom of the kiln, and receive the heat direct from the coal. These highly fired bricks are always of inferior quality and represent a certain loss.

The object of the walls which separate the compartments is to isolate them when the firing is completed, and all that need be

"FOUR λ TRANCHES" FOR TILES.

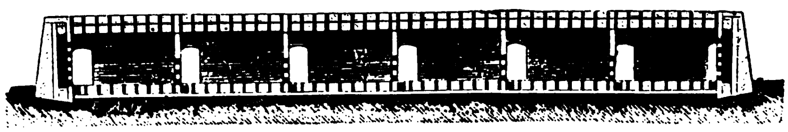


Fig. 411.—Longitudinal Section.

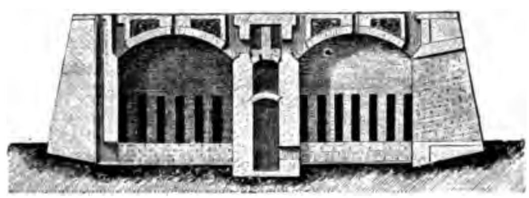


Fig. 412.—Transverse Section.

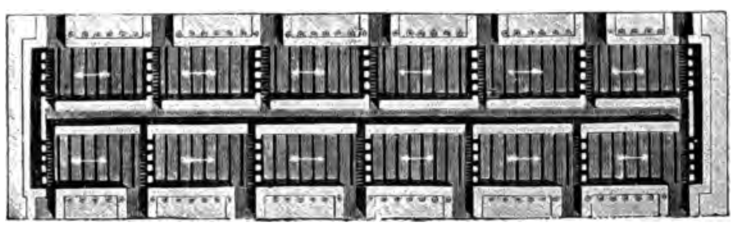


Fig. 413.—Plan.

done is to close the openings in the walls with a layer of sand or a metallic register.

As the air necessary for combustion is introduced into each compartment, and not behind the fire, the fired and isolated compartment may be allowed to cool more or less quickly, and is thus similar to an intermittent kiln.

The kindling and management of the fire differ very little from those of the Hoffmann kiln already described.

From the point of view of economy, this kiln does not present the same advantages as the Hoffmann kiln, for the outer air is not heated before it reaches the fuel, nor can we use slack, which would burn badly; but it has the advantage of a more rapid cooling when the products can bear it, and so allows of a diminution in the number of compartments. Above all, it avoids contact between the tiles and the coal.

This latter advantage is found in gas kilns, which, moreover, require no bricks for stacking, as the tiles are placed on the floor of the kiln between the refractory clay "chandelles." There is no fear of the ash stains which are produced under a high draught when solid fuel is used; and finally, the degree of firing which can be reached is much higher than in the Virollet kiln.

All these advantages should recommend gas firing to tile manufacturers, and in new installations it is undoubtedly indicated.

Stacking.—The method to be adopted depends upon the shape of the tile, and on the kiln at disposal. The important thing is to avoid warping during the firing by pressing them closely together. Fitting tiles are arranged in pairs and one close against the other, so as to take up less space and preserve the projecting parts.

Round tiles stand upright one against the other. But often several kinds of tile are fired together, and then the method of stacking depends on the special conditions.

If the firing takes place at a temperature near that of softening of the paste, special precautions must be taken to avoid loss of shape; for instance, we may stack in batches, using bricks to construct the divisions.

Installation of Mechanical Tileworks. — Details depending upon special circumstances excepted, tileworks are composed of large buildings in which the ground-floor is occupied by the kilns, machines, soaking-ditches, and deposits of prepared clay; the upper storeys are reserved for the drying-rooms.

The arrangement of the machines depends upon local con-

ditions. Figs. 414 and 415 are section and plan of an installation, and will give some idea of the arrangement.

At *a* is the machine for making the slabs, at *b* and *c* are

TYPE OF INSTALLATION OF A MECHANICAL TILE FACTORY.

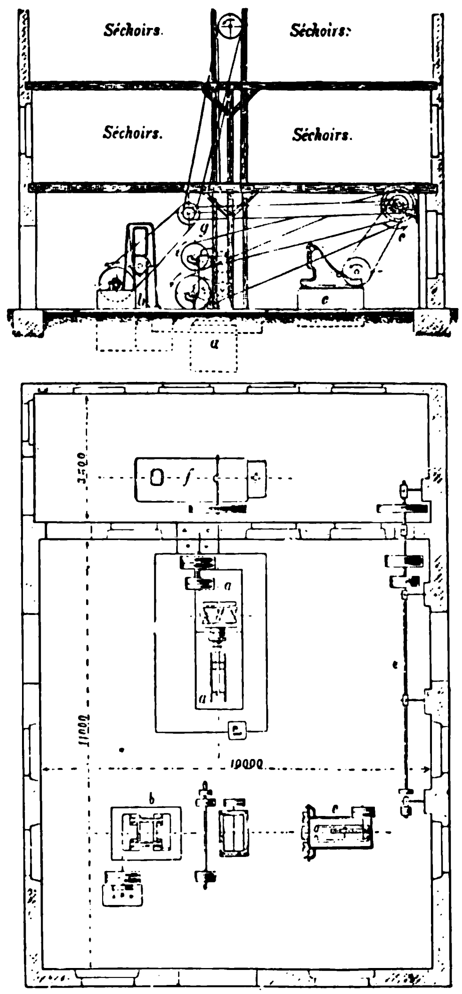


Fig. 414.—Vertical Section. Fig. 415.—Plan.

two tile presses of different type, one of which can make ridge tiles, which require a larger stroke for the upper mould. Between these two presses stands a tile-lift, worked by machinery and connecting with the upper storeys.

The estimate of such an installation is—

Movable 20 horse-power engine	12,000 fr.
1 pug-mill with crushing cylinders, 8 horse-power . .	2,750
1 expression machine, 7 horse-power	2,050
1 double-carrier lever press, 1 horse-power	2,000
1 five-sided revolver press, 2 horse-power	3,500
Matrices, moulds, etc.	1,500
Tile-lift, 2 horse-power	2,500
Transmission of power	1,000
Sundries	700
	28,000 fr.

The staff required comprises an engine-driver, a man to feed the pug-mill, a cutter for the slabs, a man to take the slabs to the presses, four men at the presses, and three men to put the tiles on the shelves: eleven men in all.

It rarely happens that the manufacture of tiles is not accompanied by that of bricks, therefore it is difficult to fix the cost of tiles alone, unless we suppose a continuous manufacture of them. In that case, the above-described installation will produce daily about 8000 tiles, that is, 2,500,000 per annum, *and the cost of* 1000 *tiles, liberally estimated, is calculated as follows*:—

Interest at 4 per cent. on 28,000 fr. = 1120 fr. }
Depreciation ,, 10 ,, ,, = 2800 } 3920 fr.

Per 1000, on an annual production of 2,500,000: $\frac{3920}{2500}$ . . . . . = 1 fr. 55

11 men at 5 fr. per day = 55 fr., or, per 1000, $\frac{55}{8}$ . . . . . . = 6 fr. 87

Coal, 250 kil. at 25 fr. the ton = 6 fr. 25 }
Oil, maintenance, etc., per day = 6 fr. 35 } 12 fr. 60, or, per 1000, $\frac{12.60}{8}$. = 1 fr. 58

Total . 10 fr. 00

To this price we must add the cost of extraction of the clay (p. 31) and its preparation, which we estimate at an average of . . . . . . 2 fr. 00

Total cost . 12 fr. 00

For a production of 20,000 to 25,000 tiles a day, which corresponds to an annual production of 6 to 8 millions, the following plant is required:—

50 horse-power steam engine, about	25,000 fr.
Rolling cylinders (these are not always necessary), 5 horse-power . .	1,800
Crushing mill, 5 horse-power	3,500
2 pug-mills, 10 horse-power, at 1800 fr. . . . . =	3,600
2 expression machines, 15 horse-power, at 2250 fr. . . . . . =	4,500
5 revolver presses (5-sided), 10 horse-power, at 3500 fr. . . . . =	17,500
2 tile-lifts, 4 horse-power, at 2500 fr. . . . . =	5,000
Matrices, moulds, etc.	5,000
Transmission of power	3,000
Sundries	1,100
Total for machines .	70,000 fr.

Net cost per 1000 *tiles.*

Interest at 4 per cent. on 70,000 fr. = 2800 fr. Depreciation ,, 10 ,, ,, = 7000	} 9800 fr. : $\frac{9800}{7000}$ . . .	= 1 fr. 40
24 men at 5 francs a day = 120 fr. per 1000 : $\frac{120}{22.5}$	. . . .	= 5 fr. 34
Coal, 500 kil. at 25 fr. = 12 fr. 50 Oil and maintenance . 10 fr. 00	} 22 fr. 50 per 1000 : $\frac{22.50}{22.5}$ . . .	= 1 fr. 00
	Total .	7 fr. 74
Extraction and preparation of the clay averages		1 fr. 76
	Total cost of moulding .	9 fr. 50

In order to obtain the total cost of installation of the tileworks, we must add to the price of the machines	70,000 fr.
That of the building, with storeys for the drying-rooms, the ground-floor being occupied by the kiln and machines, about	45,000
Continuous kiln, with chimney	35,000
Sundries	5,000
	155,000 fr.

We must add to this sum: (1) the cost of the land, (2) the cost of vehicles and horses, etc., for delivery of goods, (3) the cost of various buildings: stables, coach-houses, offices, etc.

The above figures can only serve as hints, for the plant necessary varies with the nature of the clays to be worked.

§ 3. SHAPES, DIMENSIONS, AND USES OF THE PRINCIPAL KINDS OF TILE.

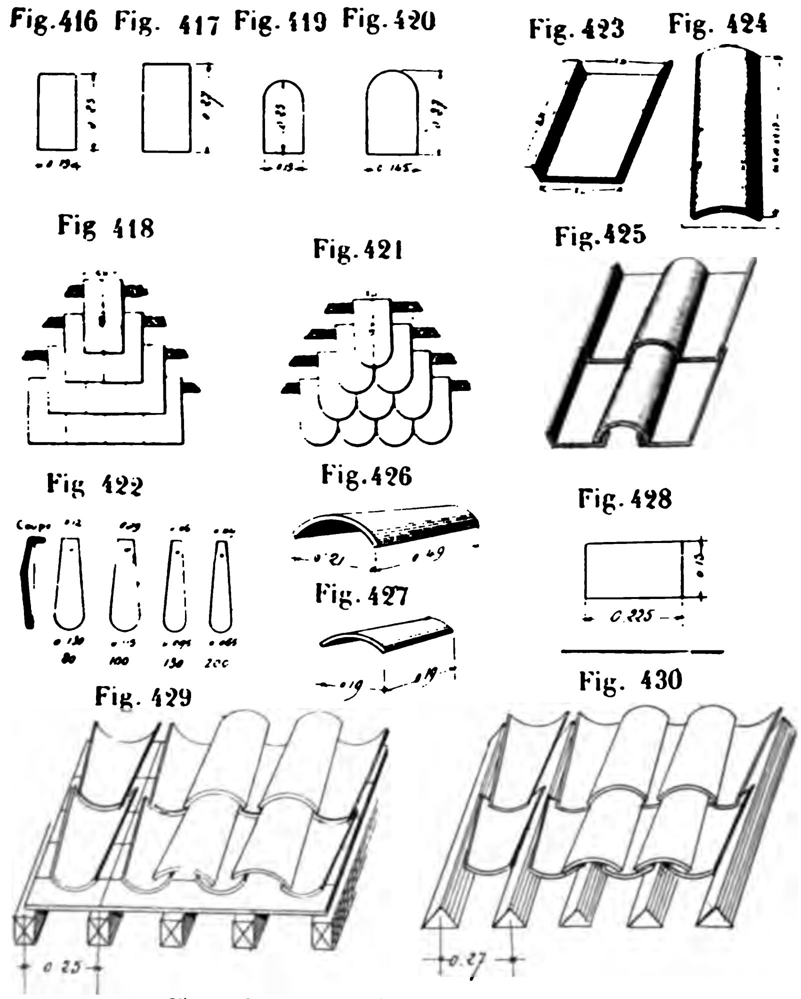
With respect to their shape, tiles are divided into *ancient tiles*, which possess no sockets and are laid one against the other, and *modern* fitting tiles.

Ancient Tiles.

These comprise tiles which are flat, square, or rounded at one end, and round or variously shaped tiles.

Flat Tiles. — *Square.* — These are greater in length than breadth, and of variable dimensions (Figs. 416, 417); the best known ones are .27 × .15 and about .015 thick (about 10 in. ×

6 in. × ½ in.); they weigh about 1 kilog. (2 lbs.). They are fixed to the laths with a hook, and most of them have one or two holes (Fig. 417), by which they can be nailed down. They are arranged in horizontal rows which overlap one another from the



Figs. 416 to 430.—Ancient Tiles of Various Shapes.

base to the ridge; only one-third of the tile is left visible, and this part is called the "*pureau*." Each tile is over three laths (Fig. 418), and thus the roofing is three tiles thick, and is of considerable weight, averaging 60 kilog. per square metre. The slope should be from .75 m. to 1 m. per metre (30° to 45°).

Round or Scaled.—These only differ from the foregoing in the lower part, which is semicircular (Figs. 419, 420), or pointed, which gives the roofing a tasteful appearance resembling the scales of fish (Fig. 421), whence the name.

In order that a roofing may be successfully laid, the tiles must be perfectly smooth, which is not often the case.

The roofing of towers and domes requires the tiles to be cone-shaped so as to follow the curvature of the roof (Fig. 422). They are laid in the same way, being nailed to the laths when necessary.

Roman Tile.—This differs very little from the tile of the ancient Romans; its shape is trapezoidal (Fig. 423), and the joins are covered by round tiles (Fig. 424). Roofings of this kind (Fig. 425) are still found in Champagne, in the south of France, and in Italy.

Round Tiles.—*Canal or Roman Tile.*—These are used alone or in conjunction with the preceding kind. In the former case they are laid in different ways according to the locality; they are generally placed upon connecting battens, for which are sometimes substituted terra-cotta squares (Fig. 428), and the whole is sometimes bound together with mortar, making a solid but very heavy mass (Fig. 429). In the south of France, the tiles are merely placed upon triangular joists (Fig. 430); the slope must not be very great, about .4 to .5 metres per metre (21° to 26°), for the tiles are only kept in position by their weight.

ᔕ-shaped Flemish Tiles.—These tiles are provided with a hook which holds them to the laths (Fig. 405), and they can therefore be more sloped than the previous kind. To make the roof more water-tight, the joins are usually filled in with mortar.

Modern Tiles.

The invention of fitting tiles by Gilardoni was a great advance on earlier tiles, which had many other disadvantages besides their weight; they offered a great hold to the wind,

they allowed snow and often rain to pass through, and they were costly to maintain.

The first tiles have been improved upon, and we possess types to-day which make excellent roofs; but modifications are always being sought after, and every year new shapes of tiles appear, which, however, are all based on the same principle, and frequently offer no sensible advantage over existing types.

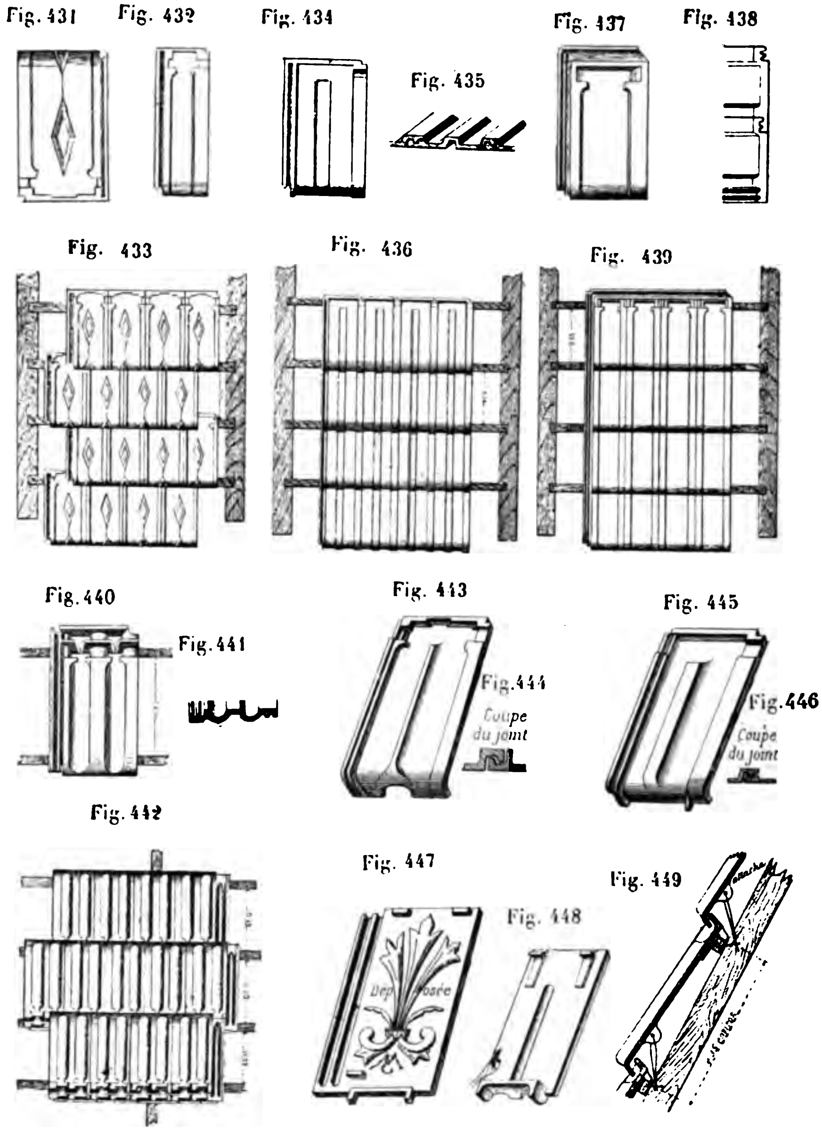
It may well be asked, with reference to this, whether inventors are well advised in trying, under pretext of improvement, to complicate the shape of tiles by an infinitude of details. What should be the natural shape of a tile that it may be suited to its destined position? This shape should be one which will render the roofs absolutely proof against snow and rain in any quantity; it should make the tiles as light as possible consistently with their stability under any pressure of wind. A detailed examination of the principal types of tile will show how this question has been answered.

Fitting tiles are divided into two classes according as they are laid overlapping, that is to say, *with vertical interrupted join*, or in a straight line, that is to say, *with vertical continuous join*.

Tiles with Interrupted Vertical Join.– *Gilardoni tile*, also called *diamond-shaped* tile (Fig. 431).—This tile has average dimensions of .4 × .24, and thirteen are required to the square metre, which represents a utilisation of five-sixths of the total surface. The joint is at the left, and is formed of a groove with a strong inner edge; at the right is the counter-joint; at the top is a simple flange.

The lower part is of larmier shape and has a hollow (Fig. 451) in the middle, in which the counter-joint of the lower row rests. In the middle of the tile is a lozenge-shaped strengthening rib, hollow inside; it is below this lozenge that the triangular projection caused by the hollow at the bottom of the tile is placed, and it has also the effect of directing water to the two sides of the lower counter-joint (Fig. 433). The tile is fastened to the laths with two hooks, and some types are furnished with holes through which they can be nailed to the rafters, others

(Fig. 448) are furnished below with a projection pierced with a hole through which a wire is passed and attached to the laths (Fig. 449).



Figs. 431 to 449.—Modern Tiles of Various Shapes (Gilardoni Brothers and Muller).

This type of tile, which was the first to be manufactured, is now made by many firms (see table), as the patent has expired.

It requires half-tiles (Fig. 432). The perfected model No. 4 (Fig. 440) is double-fitting at the top and at the side. The surface of the tile forms two channels (Fig. 441) separated by a rib.

The *tile of Martin frères*, called *Marseilles tile* (Figs. 458, 460).—The dimensions (.42 × .25) of this are almost the same as those of the lozenge tile. In the middle is a narrow rib enlarged at the base into a triangle, and as it ceases at some distance from the horizontal joint, this does not reach under the tile above. On the left side the grooves forming the joint are triple, and at the top the joint is double. The counter-joint has on it a channel which, by means of smaller oblique channels, pours off the water which falls upon it.

This tile, which is manufactured by the United Tileworks of Marseilles, makes excellent roofs (Fig. 460).

The *catch and hook tile* (Fig. 454) is a lozenge-shaped tile, the lower part of which has a fitting arrangement binding all the tiles together without its being necessary to fix them to the laths. The outer appearance of these tiles is not changed (Fig. 453).

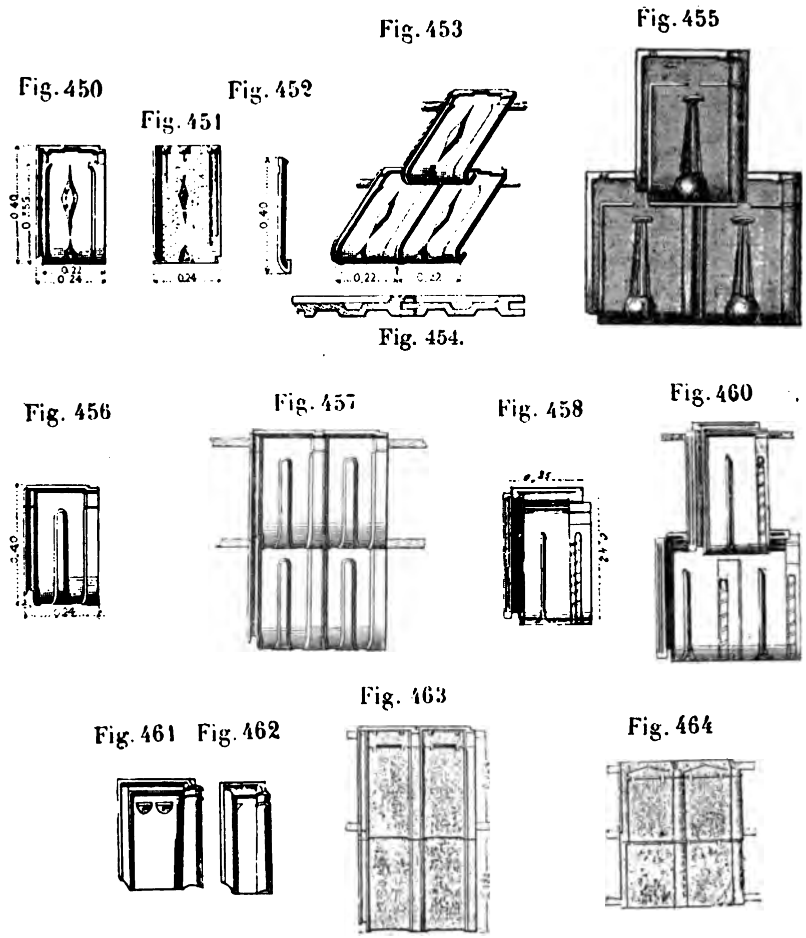
The *Boulet tile*, called also *Artois tile* or *pantile* (Fig. 455).—The middle rib ends in a rounded portion which sends the water to each side of the counter-joint. Its dimensions (.28 × .21) are smaller than those of the lozenge tile, and for each square metre twenty are required weighing about 40 kilog. This tile is principally used in the north of France and abroad.

The *villa* or *chalet* tile only differs from the preceding ones in its dimensions, which make it squarer in shape.

Tiles with Continuous Vertical Join.—*Gilardoni tile No.* 2, also called *Muller* or *ribbed* tile (Figs. 434, 445, 456).—This has the same dimensions as the lozenge-shaped tile (.4 × .24), and also is 13 to the square metre. The joint is formed by a broad and deep groove bordered through its whole length by two thin ribs; the counter-joint is formed by a broad projection provided, below and in the middle, with a rib fitting into the above-mentioned groove; the join is thus covered (Figs. 435, 446), which is not the case in the lozenge tile (Fig. 444).

A strong rib, hollow underneath, is placed in the middle of the tile and stretches over the whole width. This perfected tile has become the :

Gilardoni tile No. 3, called also *Alsace* or *Altkirch* (Figs. 437, 438, 439).—The central rib is omitted, and is transferred to



Figs. 450 to 464.—Modern Tiles of Various Shapes.

the left, where it forms the edge of the groove. The counter-joint, which is double-tongued, is fitted to it and forms with it a fairly broad relief from top to bottom of the roof. The horizontal joint is also double-fitting ; the flange of the base is larmier-

grooved; a second flange, parallel to the first, crosses the tile, fits into the groove of the upper flange, and thus forms another obstacle to the passage of water. This system is excellent.

Northern Tile, called Pantile.—The inner flange of the groove forming the joint turns back towards the top, making an angle; the counter-joint has a shoulder-piece. The tile has a single hook at the top, and at the bottom there is an angular groove fitting into the upper angular rib so as to form a joint. Such is the Legros pantile (Fig. 464).

In the Royaux de Leforest (Pas-de-Calais) tile, the upper grooving is not triangular (Figs. 461, 462).

Foreign Tiles.

These differ more or less from French tiles, but are derived directly from them.

Among those of antique shape, there are the German *flat tile* (Figs. 465, 466), which is made by special cutting machines (Fig. 382)—it has four grooves on the top for drawing off the water; the *modified Roman flat tile* (Fig. 467), carrying its own cover-joint; and the *Dutch* ∽*-shaped pantile* (Fig. 468). Flat tiles are also made which are hollow inside.

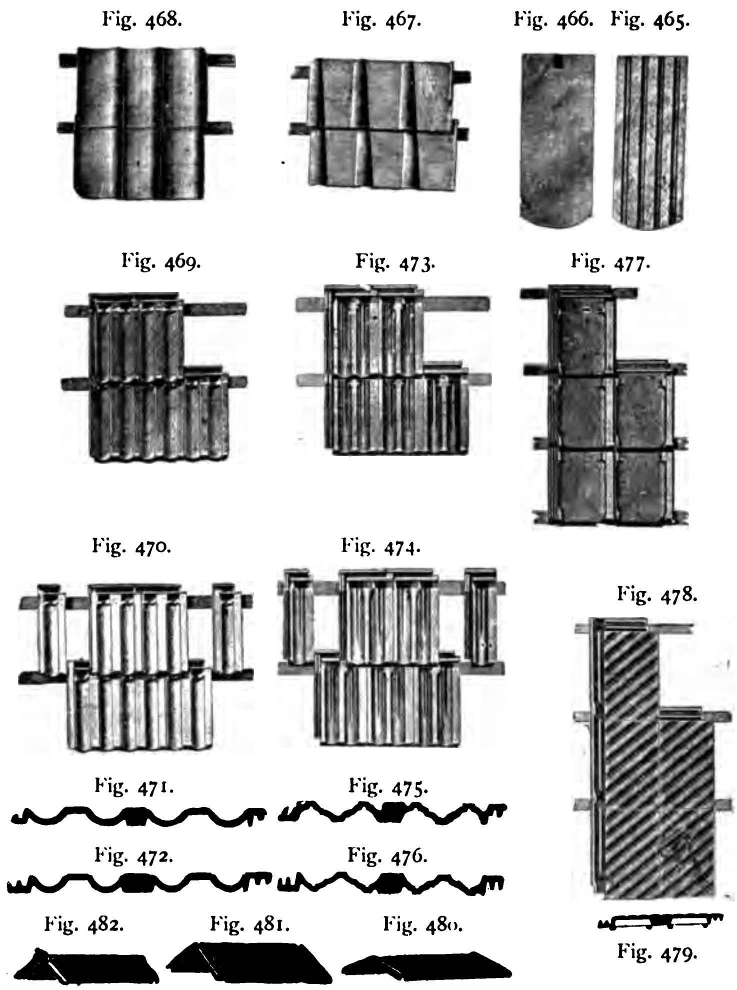
The modern French roofing tiles of the lozenge, Boulet, or Marseilles type are much used abroad. Tiles with continuous (Fig. 469) or interrupted (Fig. 470) vertical joint, and single (Fig. 471) or double (Fig. 472) overlapping, are made in Germany. The figures sufficiently explain the shape of these tiles and the way in which they fit together.

The *Italian Ludovici tile* is also made either with continuous (Fig. 473) or interrupted (Fig. 474) vertical join, and single (Fig. 475) or double (Fig. 476) fitting.

The *Porz tile* (Fig. 477) is triple, overlapping, at the top and at the side, and is very similar to the Alsace tile. The *Victoria tile* (Fig. 478) possesses no visible rib; it overlaps doubly both at the top and at the side, as the figure shows (Fig. 479).

Tiles for Special Uses.

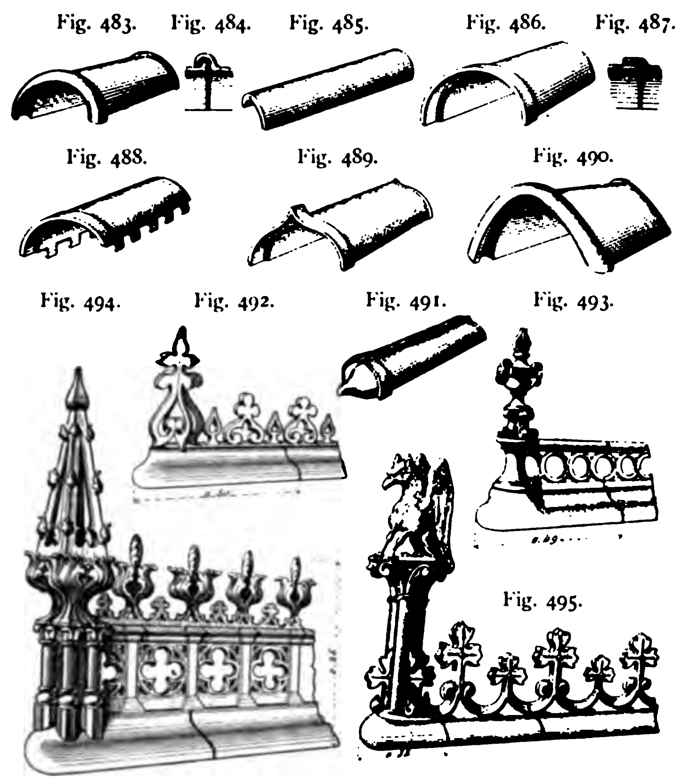
All the preceding tiles are used for covering the flat parts of the roofs ; for projecting or re-entrant parts, special tiles are required



Figs. 465 to 482.—Foreign Tiles of Various Shapes.

which take their names from the parts they cover: *ridge tiles* are placed upon the ridges, *hip tiles* on the hips, *border tiles* on the borders of the roof, etc.

Ridge Tiles.—The simplest are semi-cylindrical (Fig. 485) and of varied dimensions; they are laid down bare, one against the other, and are fixed to the plaster at the bottom and at the joins. The *fitting ridge tiles* (Figs. 483, 535) are provided with a hollow hump which is placed on a projection at the end of the next ridge tile and so forms a joint (Fig. 484). The overlapping ridge tiles (Fig. 486) are formed of a male end which fits



Figs. 483 to 495.—Ridge Tiles (Muller).

to a distance of some centimetres into the female end to form the joint (Fig. 487).

The shape of these ridge tiles is very variable; some are pointed (Fig. 489), some are *shelving ridged* (Fig. 490), some are *lozenge shaped* (Fig. 534). For fitting tiles hollow ridge tiles are made (Fig. 488), which receive the ribs of the tiles like those of the Muller type.

To strengthen ridge tiles, they are sometimes keyed (Fig. 533); this may be done simply (A and B of Fig. 533), or ornamented to give elegance to the roof. Decoration, however, is

FINIALS FOR RIDGE TILES.

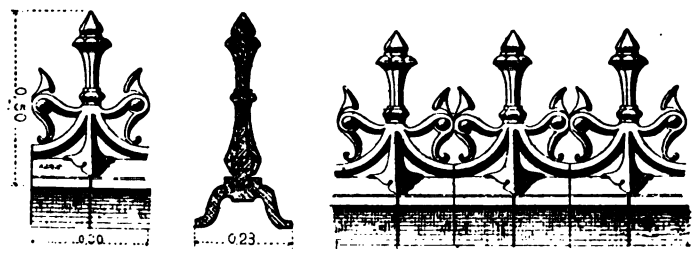


Fig. 496. Fig. 497.—Section. Fig. 498.—Application.

more usually added by means of the ridge tiles themselves, which have ornaments on them called finials. Sometimes these finials

TOP-PIECES AND SUPPORTS.

Fig. 500.

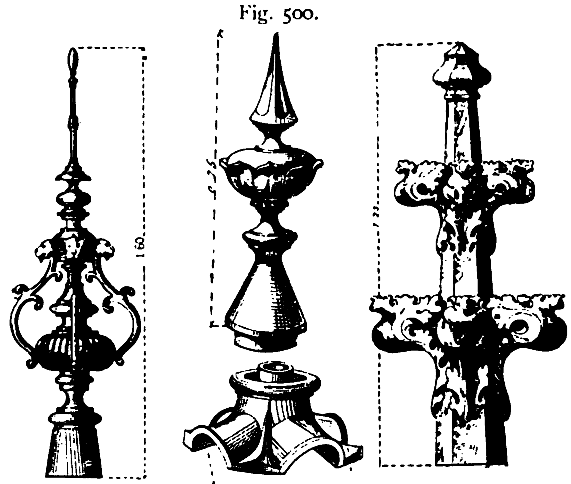


Fig. 499. Fig. 501. Fig. 502.

Fig. 499.—(Perrusson.) Fig. 500.—(Muller.) Fig. 501.—Support (Muller).
Fig. 502.—Gothic Top-piece (Brault).

are part of the ridge tile and are of varied and more or less complicated patterns (Figs. 492 to 495). The last ridge tile, called ridge end, bears a higher ornament which towers up above

the crest of the roof. Sometimes the finials are separate, and are fitted into a groove in the ridge tiles; the finial in Fig. 496, the section of which is shown in Fig. 497, and application in Fig. 498, is one of this kind. Like finials, top-pieces are either part of the ridge tiles (Figs. 494, 495) or separate (Figs. 499 to 502).

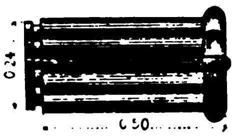


Fig. 503.—Perrusson Ridge Tile.

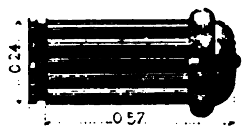


Fig. 504.—Perrusson End Tile.

The ends of ridges (Fig. 504) are more or less ornamented according to the style of the ridge tiles themselves (Fig. 503); they are divided into closed male ends to the right and closed female ends to the left. When they bear top-pieces (poinçons),

COPING TILES.

Fig. 505.

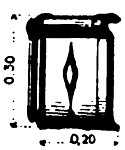


Fig. 506.

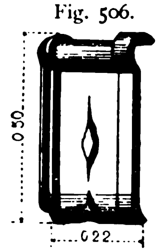
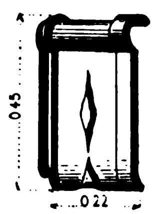


Fig. 507.



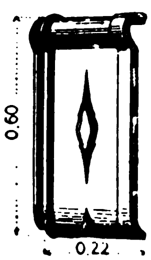


Fig. 508.

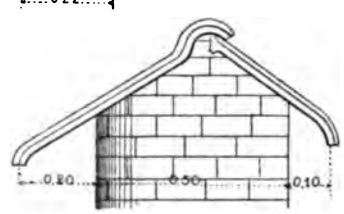


Fig. 509.—Wall with Coping Tiles.

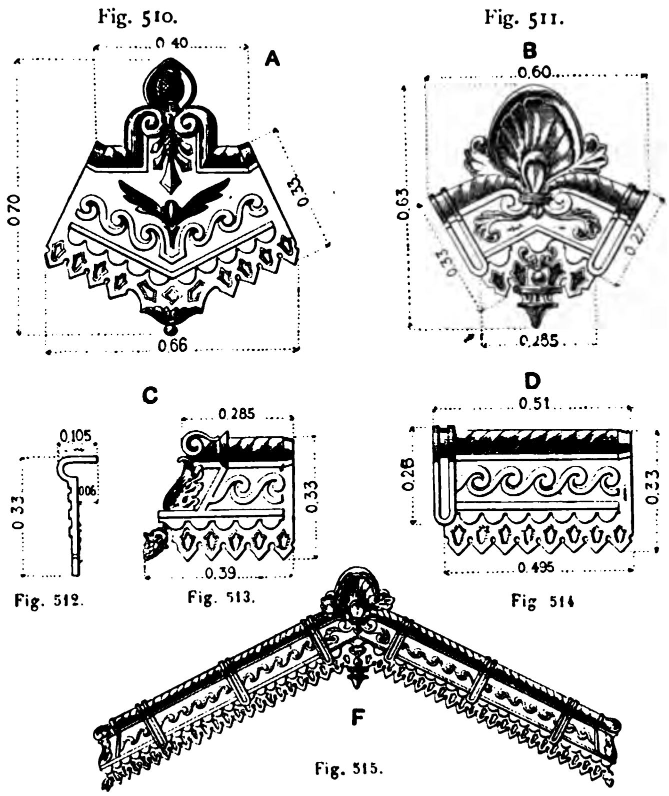
they are called poinçon-carriers. German ridge tiles are acute-angled (Figs. 480 to 482).

Hip tiles are similar to ridge tiles, and also have end tiles.

Coping Tiles.—These consist of an ordinary tile with a curved end forming a ridge (Figs. 505 to 508); their dimensions

correspond to the thickness of the walls which they are to cover. When they are too thick for a single tile, two are placed on them (Fig. 509). These tiles are also made double-sloped.

Border Tiles, Frontons, Pantile Joints.—When the ends of a roof form a gable, it is very often adorned with a border of terra-cotta, which is made up of pieces called *border tiles.* These fit



Figs. 510 to 515.—Pantile Joints, Frontons, and Borders (Perrusson).

together (Figs. 514, 522, 527), and are called *left border* or *right border* according to the side on which the counter-join is; the terminating tiles are called border ends (Figs. 513, 525, 531), and at the top of the gable the tiles are joined by a fronton (Figs. 511, 524, 529).

Borders are made plain like tiles (Fig. 536) or ornamented (Figs. 522, 527); the same may be said of frontons, and the

BORDERS, GUTTERS, FRONTONS, ANTEFIXES.


Fig. 516. Fig. 517.

Figs. 516 and 517.—Perrusson Make.

Fig. 519.

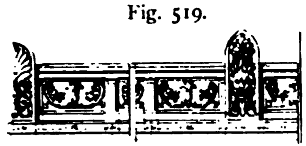
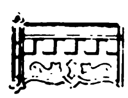



Fig. 518. Fig. 520. Fig. 521.

Figs. 518 to 521.—Muller Make.



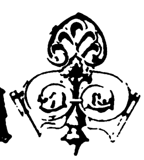
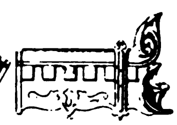
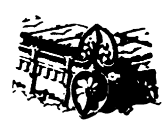
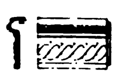
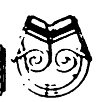
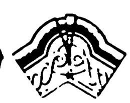




Fig. 522. Fig. 523. Fig. 524. Fig. 525. Fig. 526.

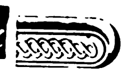
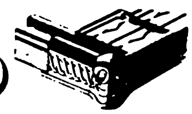



Fig. 527. Fig. 528. Fig. 529. Fig. 530. Fig. 531. Fig. 532.

Figs. 522 to 532.—Gilardoni Make.

general effect is more or less ornate (Fig. 515) according to the richness of the pattern. When ornamented, the tiles and frontons are called monumental.

A special border tile (Fig. 539) called *membron* is used to cover the angle in roofs with "*comble brisé*" (Fig. 542).

Border tiles are substituted for ridge tiles in certain special cases, as, for example, in the roofs of factories lighted from above (Fig. 540).

Pantile joints serve the same purpose for pantiles as frontons

VARIOUS TILES.

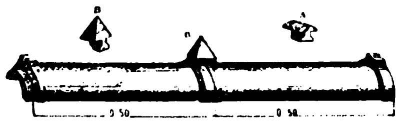


Fig. 533.

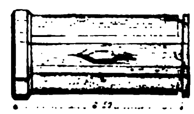


Fig. 534.

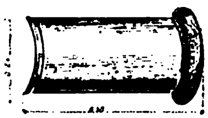


Fig. 535.

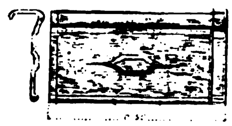


Fig. 536.

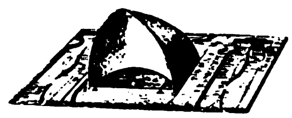


Fig. 537.

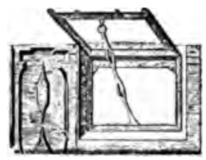


Fig. 538.

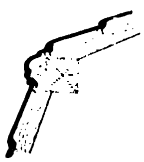


Fig. 539.

Fig. 540.

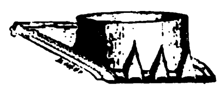


Fig. 541.

Figs. 533 to 541.—Montchanin Make.

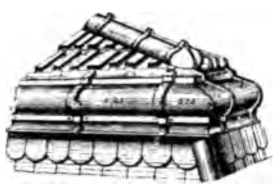


Fig. 542.

Fig. 543.

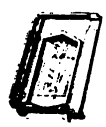


Fig. 544.

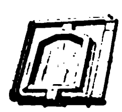


Fig. 545.

Fig. 546.

Figs. 542 to 546.—Muller Make.

for gables, but of course they are inverted (Fig. 510). They are made plain, or more or less richly decorated. In order that they may fit all slopes, they are made in two pieces, which are hinged together (Fig. 528). Frontons are made in the same way (Fig. 529).

Gutter Covers, Return Angle.—Gutter covers are similar in use

and appearance to border tiles, and the two kinds are interchangeable. Thus the border (Fig. 527) is used as such and also as gutter cover in Fig. 532. The angle of the gutter is hidden by a special piece called return angle (Figs. 523, 530). The gutter covers may be either plain or decorated, and are terminated by end pieces.

In public buildings they attain monumental proportions and

"MITRES," "MITRONS," AND CHIMNEYS.

Fig. 548. Fig. 551.

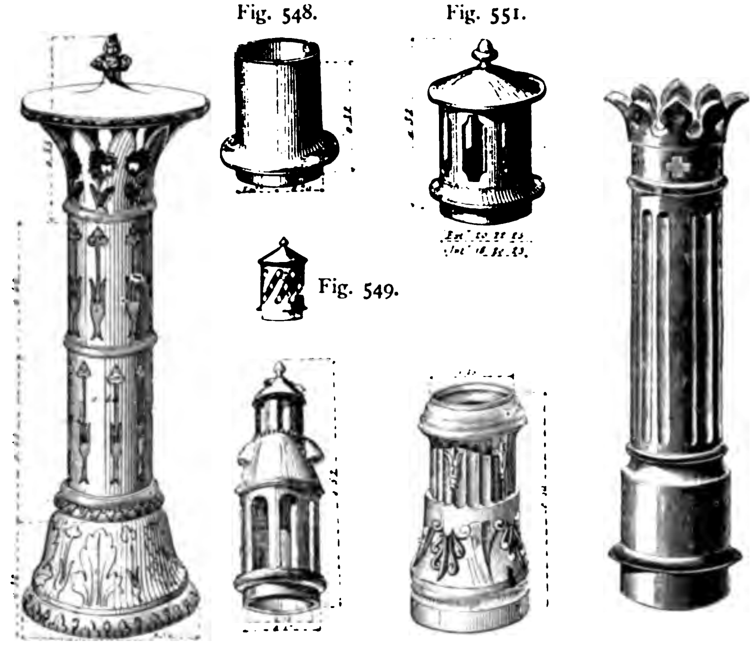


Fig. 549.

Fig. 547. Fig. 550. Fig. 552. Fig. 553.

Fig. 549.—(Brault.) Fig. 552.—(Muller.) Fig. 553.—(Montchanin, Jacob.)

contribute much to decoration. Figs. 518 to 522 give the general appearance (Fig. 519), the return angles (Fig. 518), the antefixes (Fig. 521), and the panels (Fig. 520) of the gutters of the Law Courts at Havre; they were executed by Muller.

The gutter and antefixes of the Hotel des Téléphones in Paris, executed by Perrusson, are shown in Figs. 516 and 517.

Various Tiles.—For the passage of pipes, and the lighting

and ventilation of lofts, special tiles are made. Such are *socket tiles*, which have the width of two tiles (Fig. 541) or of one (Fig. 546) according to the diameter of the pipe.

For lighting purposes, tiles are made with an orifice which is covered with a pane of glass fitting directly against the clay, the dimensions and shape being variable (Figs. 544, 545). If ventilation as well as lighting is required, a skylight sash is fitted to the opening (Fig. 538).

Ventilation alone is effected by means of tiles called "*chattières*" (Figs. 537, 543), and sometimes the orifice has a clay grating.

Fig. 554.

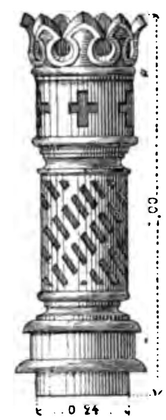


Fig. 555.

Figs. 554 and 555.—Chimneys (Perrusson).

Roofing Accessories.—These accessories are of various kinds; first the "poinçons," of which we have spoken and which are attached or not to the ridge tiles. In the latter case they fit into the end tiles. When they are placed upon several hip tiles, they are fixed to special sockets (Fig. 501). Clay *mitres* (Fig. 548) and *mitrons* (Fig. 552), *lanterns* (Figs. 549, 550, 551), and *chimneys* (Figs. 547, 553, 554, 555) may also be considered as roofing accessories; the shape of these varies from the plain upright pipe to the most elegant chimney.

Fig. 556 shows a roof which exemplifies the use of the tiles

and accessories above described. The roof, properly so called, is of lozenge tiles, and we see two "*chattières*," one open the other grated, a *window tile*, a *sash tile*, *border tiles* with *fronton* and decorated ends, *gutter covers*, *ridge tiles* with various *finials*, *poinçons*, and lastly, different terra-cotta chimneys fixed to the roof either by socket or brick masonry.

Qualities of a Good Tile, Colour.—The ideal tile should be as *light* as possible, while being strong enough to bear walking on the roofs without breaking; it should be *smooth*, *straight* in all parts, *impervious* to water; should have such a surface that water will not remain on it, and should closely follow the line of greatest slope of the roof. Finally, it should not be liable to

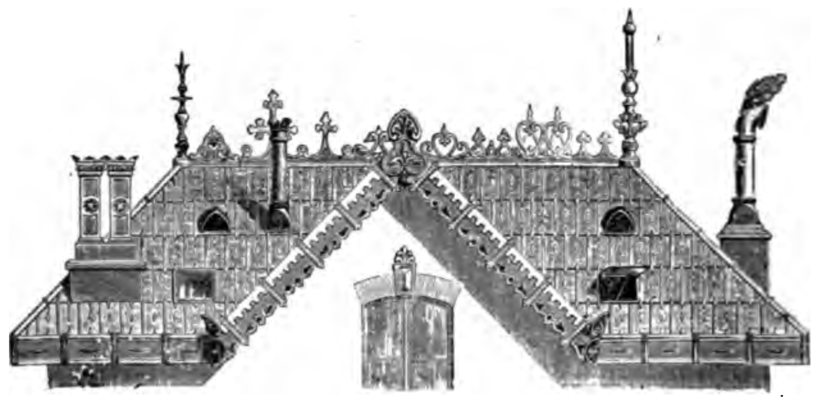


Fig. 556.—Tiled Roof with Accessories (Montchanin).

crack with frost, but should be of a nature to resist atmospheric agencies.

Which tile most nearly approaches this perfect type? It would be rash to decide without careful and comparative experiments which alone could be the basis of an opinion; we can say, however, that the Gilardoni and Muller tiles (soft clay) enjoy an excellent reputation, which is justified by their good quality; that the pantile of Leforest (Pas-de-Calais) is made of hard paste, and is highly esteemed in the north of France; that the Marseilles tile is said to be a good one. The Norman tiles, made at Dieppe and Villequier (Seine-Inférieure), at Argences (Calvados), etc., are principally used in that district.

As for the Burgundy tile (hard paste and firm paste), its red colour and quality make it much admired.

Black Tiles.

The colour of tiles depends upon the kind of clay used in their preparation, and varies from yellow ochre to vermilion red. It is important to observe that the well-fired and consequently the best tiles have a less bright and less uniform colouring than those which are less baked. At the present day less importance is rightly attached to colour, which formerly was expected to be absolutely uniform and of a brilliant red, qualities which are incompatible with those of a good tile.

Slate colour may be given artificially; this may be useful for terra-cotta objects to be placed on slate roofings, or in countries where, as in Japan, red is forbidden, but it is generally better to preserve the special properties of each building material than to hide them for the purposes of imitation.

The process for making tiles blue is the same as that used for bricks (see p. 248).

Stoneware Tiles.

To give tiles an absolute power of resistance to weather and especially frost, it was suggested that they might be made of stoneware paste, which gives impervious and therefore frost-proof products.

The clays used are similar to those employed in making stoneware pipes. The tiles are made flat or fitting (Figs. 557, 558); they are laid like ordinary tiles (Fig. 559), combined with ridge tiles (Fig. 560), borders (Fig. 562), end tiles (Fig. 561), frontons, etc., to give an elegant appearance (Fig. 563).

Besides their power of resistance to frost, stoneware tiles have the advantage of being proof against acid vapours, a quality desirable in the case of some chemical factories. Stoneware tiles do not seem as yet to be very extensively used, and this may probably be attributed to several causes: these tiles,

although hard, are very brittle, their shape is less uniform than that of ordinary tiles, as they lose shape in firing, and then, unless *very carefully* selected, the fitting sockets are not as water-

Fig. 559.

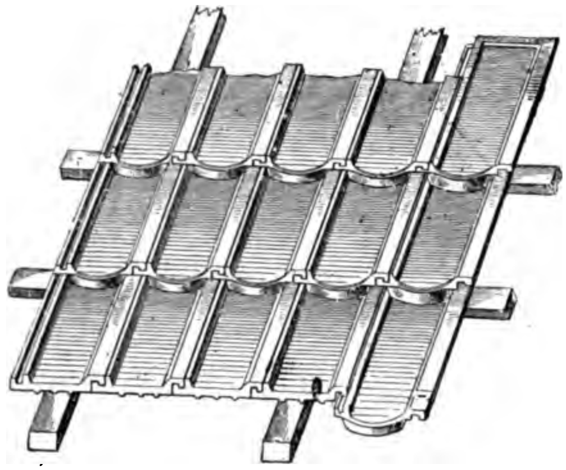


Fig. 557.

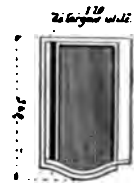


Fig. 558.

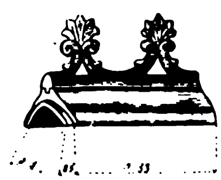


Fig. 560.

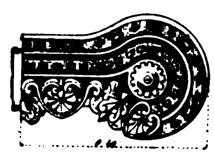


Fig. 561.

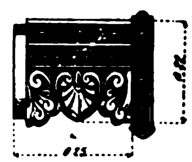


Fig. 562.

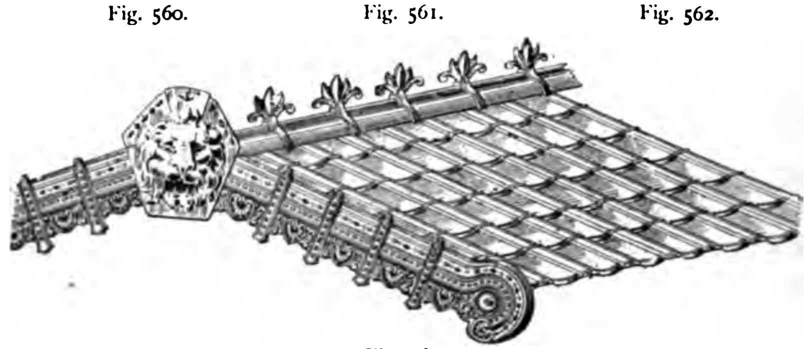


Fig. 563.

Figs. 557 to 563.—Stoneware Tiles.

proof. But it is probable that by perfecting the methods of manufacture and choosing suitable pastes these difficulties will be overcome.

PARTICULARS OF THE PRINCIPAL TILES USED IN FRANCE.

Makers.	Particulars of Tiles. Length in Metres.	Breadth in Metres.	Weight in Kilog.	Price per 1000 (1).	Per Square Metre of Roofing. Number of Tiles.	Weight in Kilog.	Price (2).	Remarks.
Ancient Tiles.								
FLAT TILES WITH HOOKS.								
Argences (3)	0.27	0.20	1.200	**35**	55	66.00	**1.82**	
	0.27	0.17	0.950	**34**	65	61.75	**2.21**	
	0.24	0.17	0.750	**32**	75	56.25	**2.40**	
Gilardoni (4)	0.35	0.13	0.750	**25**	60–75	48.75	**1.75**	Press-moulded, 50 fr.
Jacob	0.27	0.15	0.700	**60**	50–60	60.00	**3.48**	
Lartigue (5)	0.30	0.18	1.775	**60**	46	81.65	**2.76**	
Legros (6)	0.20	0.12	0.560	**18**	110	61.60	**1.98**	
Marseilles (7)	0.27	0.15	0.750	**50**	70	52.50	**3.50**	Free to l'Estaque Station.
Montchanin (8)	0.27	0.15	1.000	**60**	56–60	60.00	**3.48**	
Perrusson (9)	0.27	0.15	0.700	**60**	60–65	45.50	**3.72**	
Scale Tile.								
Argences	0.27	0.15	1.250	**60**	60–70	65–87	**3.90**	
Gilardoni	0.25	0.13	0.750	**25**	60–75	...	**1.62**	Press-made, 50 fr.
Jacob	0.27	0.15	1.000	**60**	50–60	50–60	**3.30**	
Lartigue	0.27	0.15	...	**60**	60	45–56	**3.60**	
Marseilles	0.22	0.12	0.600	**40**	90	54.00	**3.60**	Gare de l'Estaque.
	0.27	0.15	0.700	**50**	75	52.50	**3.85**	,, ,,
Montchanin	0.27	0.15	1.000	**60**	50–60	50–60	**3.30**	
Muller (10)	...	...	...	**100**	70	...	**7.00**	
	...	...	...	**175**	110	...	**8.25**	
Perrusson	0.27	0.15	0.700	**60**	60–70	40–45	**3.90**	
Royaux (11)	...	0.15	0.600	**65**	60	36.00	**3.90**	
"GIRONNÉE" SCALED TILE.								
Montchanin	0.27	0.04–0.07	0.420	**70**	...	...	...	Press-made, 80 fr.
	0.27	0.12–0.15	1.000	**70**	...	...	...	
Perrusson (Fig. 422)	...	...	...	**85**	...	...	...	Quantity to the sq. metre variable.
FLAT ROMAN TILE.								
Gilardoni (Fig. 423)	0.31	0.13–0.15	1.600	**50**	22	...	...	22 round tiles are required in addition.
Marseilles	0.43	0.28–0.34	4.500	**190**	7–8	...	...	
ROUND ROMAN TILE.								
Gilardoni (Fig. 424)	0.30	...	0.800	**20**	...	...	...	22 of the preceding flat tiles are also required.
	to	...	1.000	**25**	22	...	...	
	0.35	...	1.700	**35**	...	...	...	Moulded type, 55 fr.
Marseilles	0.44	0.18	...	...	...	...	...	
ROUND TILE CALLED "CANAL."								
Lartigue	0.50	...	2.600	**70**	25	57	**1.75**	
Marseilles	0.49	0.21	2.200	**60**	22	55	...	
	0.44	0.19	1.600	**50**	25	48	...	

(1) Catalogue prices for goods taken at the factory.
(2) Laying and laths not included.
(3) Machine tile factory of Argences (Calvados).
(4) Gilardoni Brothers, Pargny-sur-Saulx (Marne).
(5) At Auch (Gers).
(6) At Dieppe (Seine-Inférieure).
(7) Société Générale des Tuileries de Marseille.
(8) Grande Tuilerie de Bourgogne at Montchanin (Saône-et-Loire)
(9) Perrusson and Desfontaines at Ecuisses (,, ,,).
(10) At Ivry-Port (Seine).
(11) At Leforest (Pas-de-Calais).
(12) Jacob frères et fils, at Navilly (Saône-et-Loire).

PARTICULARS OF THE PRINCIPAL TILES USED IN FRANCE.

Makers.	Particulars of Tiles. Length in Metres.	Breadth in Metres.	Weight in Kilog.	Price per 1000.	Per Square Metre of Roofing. Number of Tiles.	Weight in Kilog.	Price.	Remarks.
Modern Tiles with Interrupted Vertical Join.								
LOZENGE TILE OR GILARDONI NO. 1.								
Argences . . .	0.40	0.24	2.600	**145**	13	33.800	**1.88**	
Gilardoni No. 4 (Fig. 440)	...	...	2.700	**150**	15	40.500	**2.25**	
Gilardoni No. 1 (Fig. 431) . . .	...	...	2.900	**140**	15	43.500	**2.10**	
	...	...	3.300	**105**	13	42.900	**1.36**	
Jacob . . .	0.40	0.24	3.300	**110**	13	42.900	**1.43**	
Lartigue . . .	0.41	0.25	2.900	**120**	20	58.000	**2.40**	
Marseilles. .	0.39	0.23	2.600	**70**	16	41.600	**1.12**	Single covered.
	0.42	0.25	2.450	**60**	13.5	...	**0.81**	(Fig. 438) triple cove
Montchanin .	0.40	0.24	3.100	**110**	13	40.300	**1.43**	
	0.50	0.24	5.000	**200**	10	50.000	**2.00**	Used specially for c ing walls.
Muller . . .	...	...	3.000	**200**	13	39.000	**2.60**	
Perrusson. . .	0.40	0.24	3.150	**115**	12–13	39.000	...	Are made fitting, or single or double h
VILLA OR CHALET TILE.								
Argences . . .	0.34	0.21	2.200	**120**	17–18	38.500	**2.10**	
Lartigue . . .	0.30	0.22	1.675	**80**	20	33.500	**1.60**	
Legros . . .	...	...	1.900	**65**	21	39.900	**1.36**	
Montchanin . .	0.28	0.17	1.500	**90**	27	40.500	**2.43**	
Perrusson. . .	0.35	0.22	2.300	**100**	17	35.000	**1.70**	
BOULET, ARTOIS, OR PAN TILE.								
Montchanin . .	0.28	0.20	1.800	**90**	20	36.000	**1.80**	
Legros . . .	..	...	2.000	**65**	20	40.000	**1.30**	
Perrusson. . .	0.29	0.22	2.000	**90**	20	40.000	**1.80**	
Tiles with Continuous Vertical Join.								
GILARDONI NO. 2, ALSO CALLED MULLER OR RIB TILE.								
Argences . . .	0.40	0.24	2.600	**145**	13	33.800	**1.88**	
Gilardoni No. 2 (Fig. 434) . . .	...	...	3.300	**150**	14	46.200	**2.10**	
Montchanin . .	0.39	0.24	3.200	**110**	14	44.800	**1.54**	
Muller (Fig. 443) .	...	...	3.000	**200**	14	42.000	**2.80**	
Perrusson (Fig. 456).	0.40	0.24	3.500	**130**	14.5	51.000	**1.88**	
GILARDONI NO. 3, CALLED ALSO ALSACE OR ALTKIRCH TILE.								
Gilardoni (Fig. 437) .	...	...	3.000	**150**	15	45.000	**2.25**	
Montchanin . .	...	...	3.200	**110**	14.5	46.400	**1.59**	
Perrusson . .	0.43	0.23	3.500	**120**	13.5	47.250	**1.62**	
Muller . . .	...	...	2.800	**200**	15	42.000	**3.00**	
NORTHERN TILE, CALLED PANTILE.								
Legros . . .	...	...	1.600	**52**	22	35.200	**1.14**	
Royaux . . .	...	...	1.700	**80**	22	37.400	**1.76**	
Tiles of Unglazed Stoneware.								
Bossot (1). . .	0.30	0.18	...	**90**	25–26	...	**2.35**	
Jacob et Cie. (2) .	0.34	...	2.300	**130**	17	39.100	**2.21**	

(1) At Ciry-le-Noble (Saône-et-Loire). (2) French Stoneware Company, Pouilly-sur-Saône (Côte-d'(

CHAPTER V.

PIPES.

THE use of hollow conduits made of baked clay in buildings dates as far back as that of bricks; this has been proved by excavations made in Asia Minor.

The Romans frequently used pipes of pottery to distribute water, and pipes of rectangular section to conduct the hot air which heated their baths.

After their time, these products were very little used, and it was not until the 19th century that they acquired real importance with the manufacture of drain pipes, which began in England at the end of the 18th century, and that of round or square hollow pottery, which dates from the beginning of the 19th century. Then came the introduction of glazed stoneware pipes, which are so valuable in the distribution of water. For a long time the pipes were fashioned by hand, by a series of long and difficult operations. The first attempts at machine-manufacture were made in France, about 1858, by Reichenecker, at Ottweiler (Upper Rhine). The use of machinery extended rapidly, and on all sides appeared different types of machine, all based on the principle of the macaroni press.

Omitting drain pipes, which are not directly concerned with architecture, hollow conduits may be divided into—

I. *Water distributing pipes.*

II. *Pipes for chimneys.*

I. WATER DISTRIBUTING PIPES.

These are made of ordinary clay or stone-clay. The latter are always glazed, and will be considered under the head of composite pottery.

Manufacture.

This comprises, as usual, the preparation of the pastes, moulding, drying, and firing. The choice of clay depends upon the quality of the pipes to be manufactured; for ordinary pipes, such as drain pipes, the clays which are used for hollow bricks will be sufficiently good.

But if a better quality is required, a certain quantity of rich clay must be mixed with the poor clays.

Whatever the composition of the mixture may be, it undergoes preparation by rollers and pug-mills, which convert it into a homogeneous paste free from all impurity and ready for moulding.

Moulding.—This is done by machines, as in the case of hollow bricks; the clay, which has been suitably prepared, is pressed into a closed space furnished with a die having an annular orifice of the diameter required for the pipe. One or several pipes may be produced at once, according to the magnitude of this diameter. If it is not very great, the pipes are received upon horizontal cutting-tables similar to those used for bricks. Drainage pipes are so treated; but for pipes of large diameter, these cutting-tables must be modified, or, better still, machines expressing vertically may be used.

The machines used for pipe-making are thus—

1. *Machines expressing horizontally*; 2. *Machines expressing vertically*. They may be worked by hand or power.

1. **Machines Expressing Horizontally.**—*A.* WORKED BY HAND.—These are used in small factories for making hollow bricks and drain pipes. One of the best-known types (Fig. 564) consists of two iron boxes in which two pistons, moving in opposite directions, work, one compressing the clay while the other returns. Advantage is taken of this return to introduce the clay, which has been previously blended and prepared. If it contains no impurities such as roots, hard lumps, etc., the machine is double-actioned, that is to say, each end is furnished with a die and cutting-table; but if the clay contains impurities,

it is better to sift it by passing it through a metallic sieve sufficiently fine to retain the foreign substances. This is fixed to one of the boxes of the machine; the clay is caused by the compression to pass through it, and is afterwards placed in the

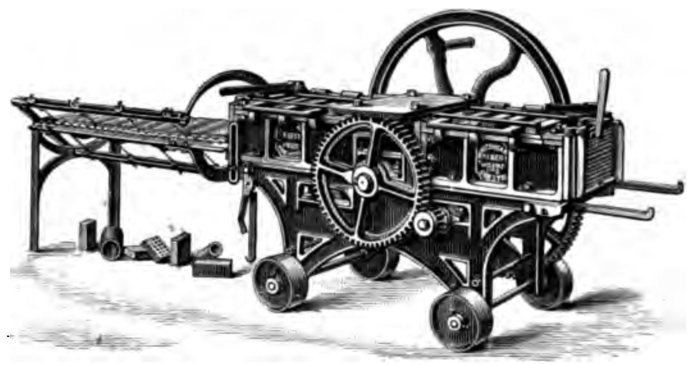


Fig. 564.—Piston Expression Machine, worked by Hand (Whitehead).

other box, whence it issues in the form of piping. The machine in this case becomes a single-action one.

B. Worked by Steam.—In the Whitehead machine, the compression of the clay is always effected by means of a piston

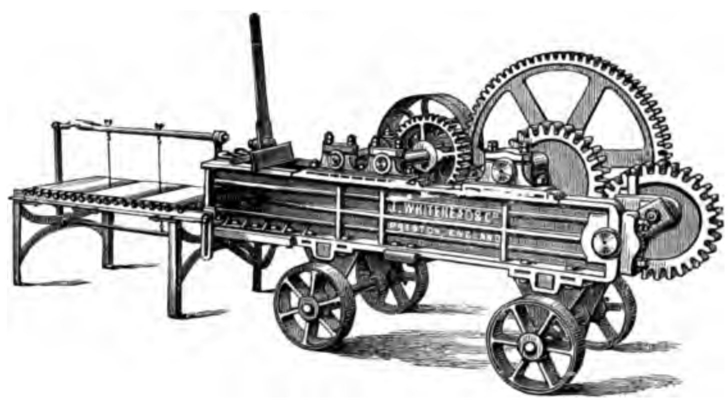


Fig. 565.—Piston Expression Machine, worked by Steam (Whitehead).

worked by cog-wheels (Fig. 565), which are so arranged that the return, that is the waste movement is made at great speed. As there is no lid to be raised before introducing the clay, the production is increased. The machine is filled during the return motion of the piston.

The diameter of the pipe which can be made with this machine does not exceed 6 inches, but by means of what is called an expansion mouthpiece (Figs. 566, 567), which is fitted to the box, we may increase the diameter to a foot.

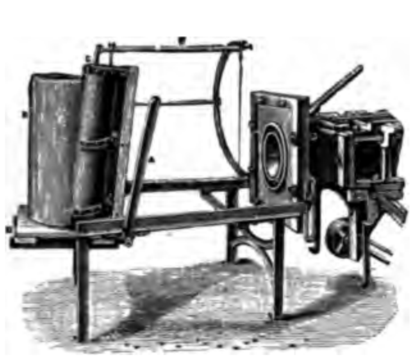


Fig. 566.—Pipe cut and raised (Whitehead).

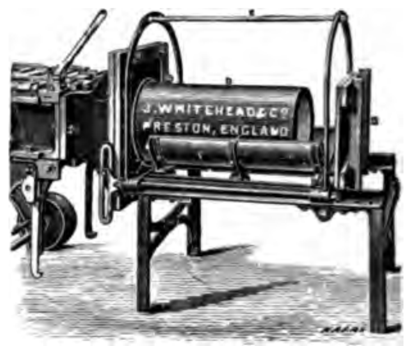


Fig. 567.—Pipe issuing from the Die (Whitehead).

The cutting-table is provided with a cradle of the same curvature as the pipe. The frame E carries the cutting-wires, and the swinging shelf B receives the pipe.

Formation of the Socket of Tiles.—The preceding machines

Fig. 568. Pipe before.

Fig. 569.—Apparatus for forming the Socket of Pipes (Whitehead).

Fig. 570.— Pipe after.

only produce smooth pipes. To form the socket, we use a table provided with a metal mould, which consists of two parts turning on a hinge and fixed together by a bolt. At one end of this mould, a movable mandrel of the same diameter as the socket is moved horizontally by a system of levers (Fig. 569).

The smooth pipe (Fig. 568), having a mandrel inside it, is placed in the mould, which is closed over it; the lever in front of the table is then moved, the movable mandrel is forced into the pipe, and the socket is formed (Fig. 570).

The expression machines used for making bricks, if provided with suitable dies, may be used for pipes of small diameter. As in the case of hollow bricks, it is better to choose machines of small or medium production, in preference to large ones which produce more than is necessary for hollow articles.

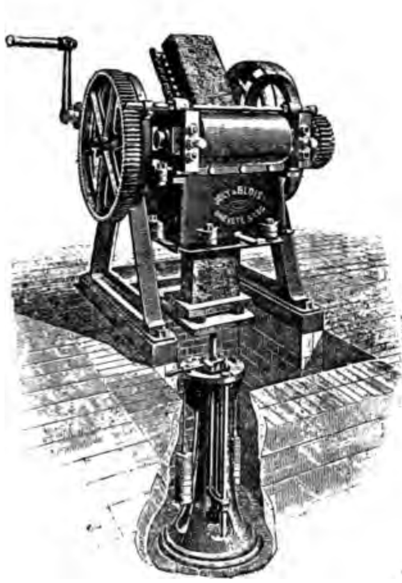


Fig. 571.—Vertical Expression Machine, worked by Hand (Joly).

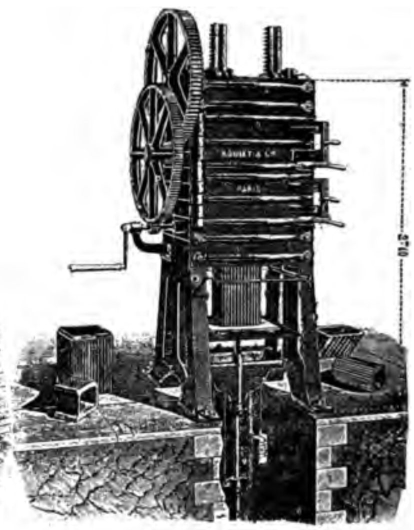


Fig. 572.—Vertical Expression Machine, worked by Hand (Boulet).

2. **Machines Expressing Vertically.**—*A*. WORKED BY HAND.—The Joly machine (Fig. 571) is composed of the same parts as the one already described (Fig. 101), but, by a change of position, the die is now horizontal. The cutting-table is replaced by a flat receiver balanced with counterpoises. This receiver is placed against the die, the machine is set in motion, the pipe issues from the die and presses against the receiver, which descends,

since, being balanced, it only requires a slight force to move it. When the required length is reached, the machine is stopped, and the pipe is cut by means of a horizontal curved frame provided with a stretched wire. The pipe is removed, the receiving table is raised again, and the operation continues. With skill the workmen succeed in making the production almost continuous, for the clay is introduced between the cylinders without the machine being stopped, as is necessary in the piston machine (Fig. 572). In this machine a piston with double rack-work compresses the clay in a box the bottom of which forms the die. One of the sides of this box is movable, and is used for introducing the paste. This must be well compressed in order to avoid the presence of air, which would produce hollows in the walls of the pipes.

Fig. 573.—Vertical Expression Machine, worked by Hand (Chambrette-Belon).

The Chambrette-Belon machine (Fig. 573) is used for making fitting pipes; for that purpose the die is provided, at the annular orifice through which the pipe passes, with a curved edge of the external shape of the socket. The receiving plate, which in this machine is above, is provided with a mandrel of exactly the same shape as the inner surface of the socket. If, then, this mandrel is placed against the die, the annular space left between the edge of the die and the mandrel will represent the socket. Hence the machine works as follows: The workman holds the plate against the die, the top of the clay issues, and meeting the mandrel spreads out so as to occupy the space between the edge of the die and the plate; the socket is thus made, and rests against the receiver, which is pushed up

by the pressure of the clay issuing from the normal orifice of the die. The pipe is then cut with a stretched wire.

The loading of the machine with clay is effected by making the die turn upon a hinge.

The Whitehead machine (Fig. 574) is of the same type as the preceding one, except that the receiving plate is below instead of above the die.

Hand-worked machines are used in small factories and for making fitting pipes of small diameter.

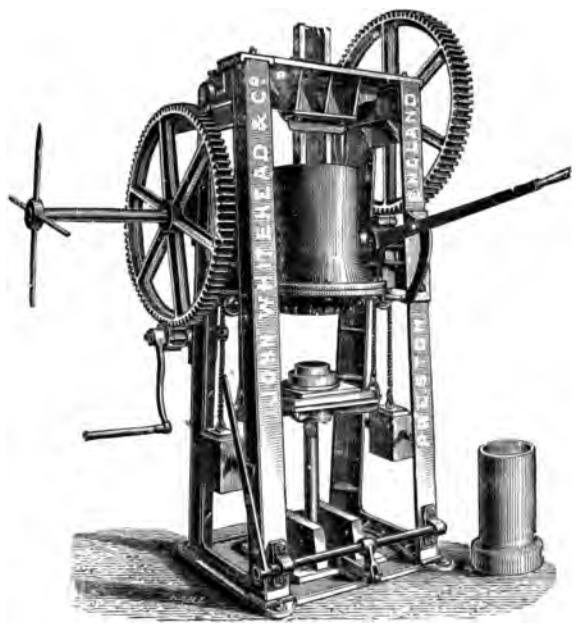


Fig. 574.—Vertical Expression Machine, worked by Hand (Whitehead).

B. WORKED BY STEAM.—These are expression machines similar to those described in the chapter on brick-making but have a horizontal die. A single machine may even be used for both positions; the Joly machine (Figs. 101, 575), for instance, is turned round on an axis by means of the screw L and the nut M, so that the die can be made either vertical (Fig. 101) or horizontal (Fig. 575).

All that need be done, then, to adapt this machine for pipe-making is to place it over a pit which will admit the balanced

receiving plate, and to provide it with a suitable die like the one shown in the figure.

In order to avoid having a pit, vertical machines with propelling cylinders are constructed, which rest upon cast-iron supports; between these is the receiving plate, balanced by counterpoises inside the supports. The machines are filled with clay from the pug-mill by means of a floor built at the level of the cylinders. This machine can make pipes 4 feet long.

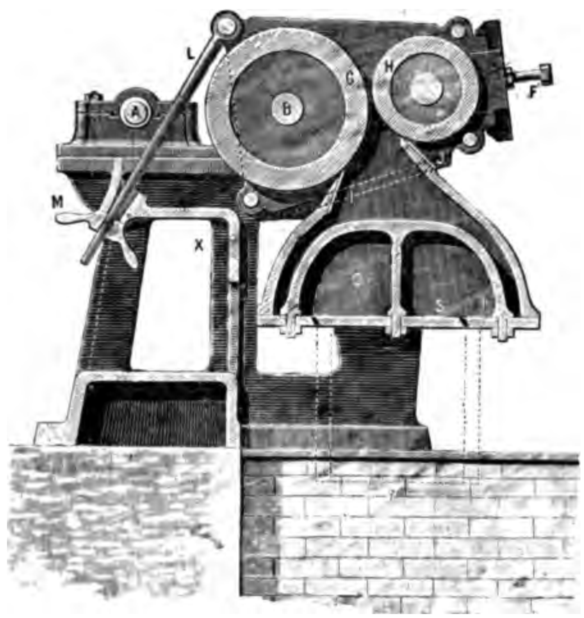


Fig. 575.—Vertical Expression Machine (Joly).

The Chambrette-Belon machine (Fig. 578) resembles the preceding one, but has only one support; pipes 4 feet in length can be made by it.

Some machines (Fig. 576) are placed upon one floor, while the lower storey contains the receiving plate, and the counterpoises are in a pit. All the preceding machines are provided with a special arrangement for throwing out of gear, usually a check pulley with belt and coupler, which allows of instant stoppage and starting. Piston machines may also be worked by steam. Fig. 579 shows an arrangement of this kind.

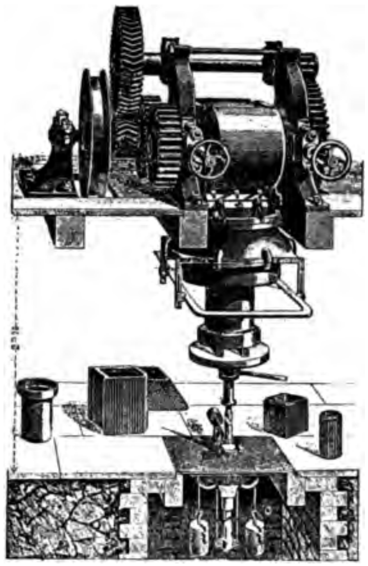


Fig. 576.—Vertical Expression Machine (Boulet).

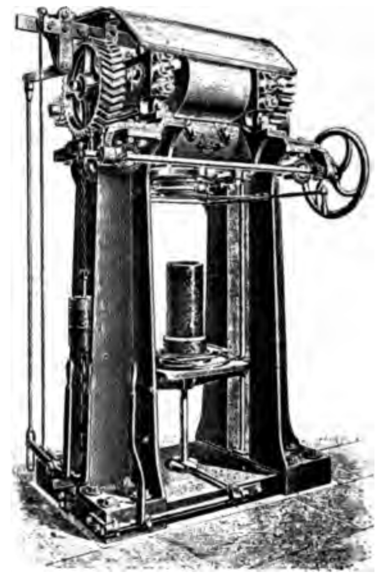


Fig. 577.—Vertical Expression Machine with Cast-iron Frame (Joly).

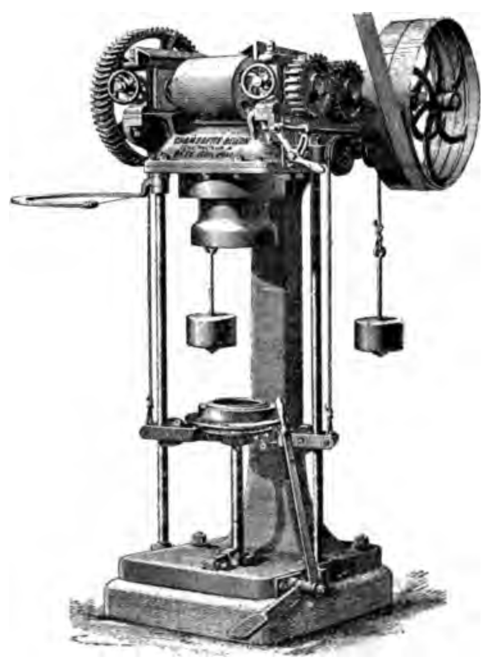


Fig. 578.—Vertical Expression Machine with Cast-iron Frame (Chambrette-Belon).

To make sure of a continuous service, the machine is provided with two cylinders turning round one of the uprights of the machine. One is being filled while the other is empty.

The direct action of steam has been used to produce pipes of large diameter. The piston-rod of a steam cylinder (Fig. 580) works another piston, which compresses the already blended clay; this is placed in a cylinder below the first one, and fitted at the

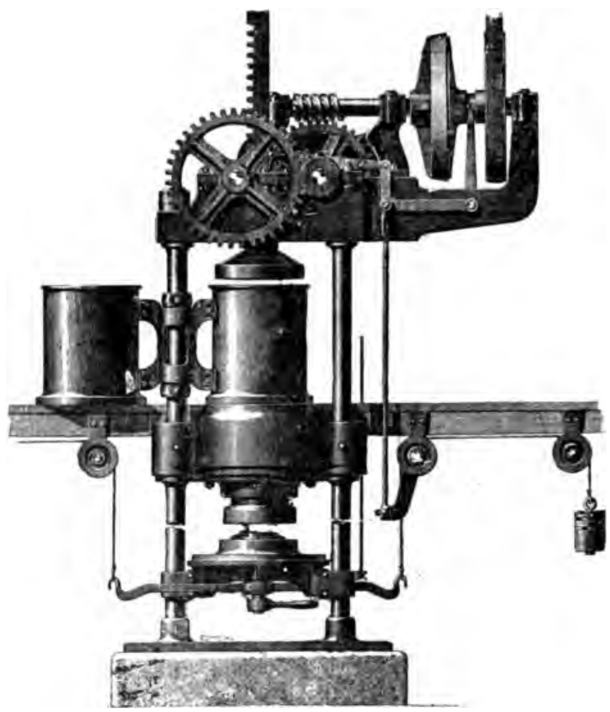


Fig. 579.—Piston Machine, worked by Steam (Chambrette-Belon).

bottom with a special die for large production. The table which receives the pipe is balanced.

When pipes reach a large size, their weight is considerable, and the handling of them becomes difficult; in this case the plates which are to receive them are placed on a truck running on a railway.

Dies.—For drain pipes the dies are made as for hollow bricks; for fitting tiles, water-effect dies are used, entirely of

metal and the principal parts of bronze; or else the orifices are provided with a layer of plaster, supported and consolidated by a

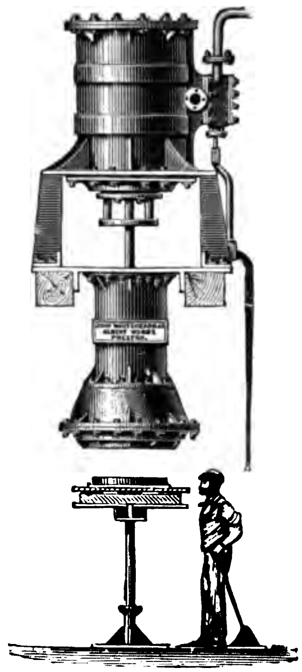


Fig. 580.—Vertical Direct-action Expression Machine (Whitehead).

metallic covering which prevents it from bursting under the pressure of the clay. Each die has one or several openings according to the diameter of the pipe to be made. Fig. 581 represents

Fig. 581.—Die for Pipes.

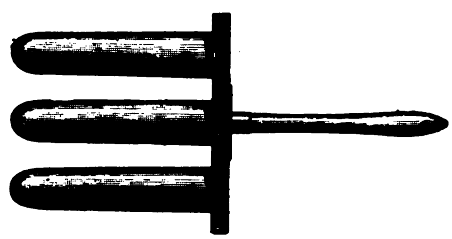


Fig. 582.—Fork-shaped Mandrel for handling Pipes.

a square die with three openings which is suitable for the horizontal Whitehead machine.

The fresh pipes are handled by means of mandrels, which are arranged on a fork and are pushed into the inside of the pipes.

DETAILS OF PIPE AND POTTERY MACHINES.

Makers.	Number.	Pulleys. Diameter in Metres.	Pulleys. Number of Turns.	Weight.	Horse-power required.	Production per Hour.	Price in Francs. Without Moulds.	Price in Francs. With Moulds.	Remarks.
MACHINES WORKED BY HAND.									
Boulet (Fig. 572)	...	...	...	2000	...	4000–5000	...	...	Specially used for "boisseaux," "wagons," etc.
Joly (Fig. 571)	2	...	...	1000	...	...	...	...	
Laeis et Cie.	...	...	...	1300	...	...	1250	1500	Whitehead double-action type.
Whitehead (Fig. 564)	2	...	...	1500	...	1000–1200	975	1500	Specially used for drain pipes, but also makes other products.
,, (Fig. 574)	...	...	...	2600	...	...	1650	2750	Specially used for fitting pipes.
MACHINES WORKED BY STEAM.									
Boulet (Fig. 576)	...	0.75–0.11	140	2800	3–4	...	...	...	
Joly (Fig. 577)	...	0.60–0.10	80	2800	5	50–100	...	2500	With a die, maximum length of product 1.3 m. = 4 feet.
Sachsenberg	1	0.78–0.10	70	2200	3–4	From 10 to 100 pipes of 50 to 600 mm. diameter.		2400	
,,	2	0.78–0.10	90	3000	4 5			2720	
,,	3	0.63–0.20	100	4800	5–6			3500	
Whitehead (Fig. 580)	...	...	...	8400	Steam at 3 kilog.	...	...	6625	7 moulds included, for pipes of 80 to 460 mm. diameter.
,, (Fig. 565)	Albert.	...	...	1830	2	...	...	1500	,, ,, ,, ,,
DETAILS OF QUARRY PRESSES—WORKED BY HAND.									
Bernhardi Sohn (Fig. 606)	10	...	...	1300	...	150	1200	...	Pressure from above and from below.
Jäger (Fig. 604)	455	...	...	1200	...	...	...	1200	
Laeis et Cie. (Fig. 605)	...	...	...	850	...	...	800	...	
WORKED BY STEAM.									
Bernhardi Sohn (Fig. 608)	11	0.65–0.10	130	4000	4	400	3000	...	Pressure from above and from below.
Jäger (Fig. 607)	128	...	...	...	...	400	...	3000	Pressure exerted is about 70 tons.
HYDRAULIC PRESSES.									
Boulet (Fig. 791)	...	...	...	1900	...	80	...	With 3 moulds.	The pump (Fig. 790) requires 1 horse-power and serves 2 presses.
Laeis et Cie. (Fig. 792)	I	...	...	1700	Variable.	...	...	1600	Works with a hand-pump.
,, (Fig. 793)	IIa	...	...	1900	Variable.	...	...	2600	
,,	III	...	...	2570	Variable.	...	...	3200	Works with pump or accumulators (4000 to

Polishing and Finishing of Pipes.—Ordinary pipes used for drains do not undergo any process after their issue from the machine, except a rough polishing, which is effected by rolling them one by one on a level stone when they have acquired a certain degree of dryness. This rolling at the same time gets rid of the malformations which sometimes occur during drying.

High-class pipes undergo a more complete finishing. When they have acquired in the drying-shed a sufficient degree of consistency, they are placed on a special lathe composed of two rollers, which are rotated and make a certain angle with one another.

The clay pipe is placed on these rollers, leaving the socket outside; friction makes them begin to turn; the length is then tested, and the excess is taken off with a sharp instrument. Then callipers are introduced into the pipe to make the inner surface regular. The socket is polished by turning, and a hollow spiral is marked out with a wooden point on the inside to hold the mortar and increase adhesiveness.

When finished, the pipe is taken back to the drying-shed to complete its desiccation.

Pipes of Special Shape.—Expression machines only allow of the manufacture of straight pipes and, by heading the fresh pipe with the hand as it issues from the die, of those having a slight curvature.

When the curvature is too pronounced (Fig. 585), we must have recourse to moulding, and this is done in plaster moulds which are in two parts, and have a central core equal in breadth to the inner diameter of the pipes to be manufactured. As for the single (Figs. 584, 588), double (Fig. 586), or perpendicular (Fig. 587) junction pipes, they are made by hand. We take two pipes which have been expressed by the machine and are sufficiently firm; by means of templates the part where the junction is to be is cut out and removed from each pipe, then the join is made in the usual way by thoroughly welding together the clay of the two pipes.

Drying.—Drain pipes are dried in the open air under sheds in which are arranged horizontal wooden shelves; the pipes are

laid flat upon these, and are turned over from time to time to assist desiccation.

Socket-tiles are dried in storeyed drying-places, and are simply placed socket downwards on the floor. The volume of these pipes being large (diameters vary from 2 to 20 inches, and even more for certain pipes of limited sale), a large space is required.

Firing.—All brick-kilns are available for firing pipes; intermittent covered kilns are used, but preferably continuous kilns. The pipes are placed upright, side by side, small ones being put inside larger ones to economise space. The fire is managed as

Fig. 583. Fig. 584. Fig. 586. Fig. 587. Fig. 588.

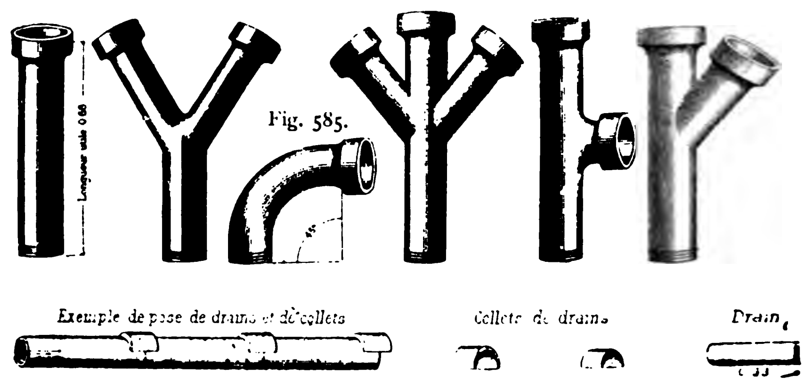


Fig. 589. Fig. 590. Fig. 591.

Figs. 583 to 591.—Pipes for Water Conduits (Brault) and for Drains (Legros).

in the case of bricks, but its action is more rapid on account of the thinness of the products being baked and the frequent vacant spaces.

II. CHIMNEY CONDUITS.

These are divided into *ventiducts* or *round* "*boisseaux*" (Fig. 592), *rectangular* "*boisseaux*" (Fig. 593), and "*wagons*" (Figs. 594, 595), more especially used in Paris.

They are made like other pipes, with machines expressing vertically. The oblique or canted "*wagons*" are made by inclining

the receiving plate. The socket of the "*boisseaux*" is cut out of the thickness of the sides, and this is done by hand when the paste is firm enough to keep its shape. At one end paste is taken away from the outside, and at the other from the inside.

To make connection between the "*wagons*," they are provided with projections which fit together. These projections are made by the machine when they are continuous, like the dovetails on straight (Fig. 600) or oblique (Fig. 601) "*wagons*"; when they are interrupted (Figs. 598, 599), they are made by hand.

The dimensions of "*wagons*" and "*boisseaux*" are extremely

Fig. 592.

Fig. 593.

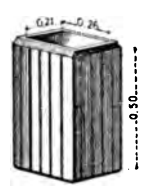
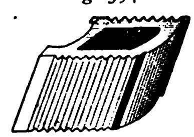


Fig. 594.



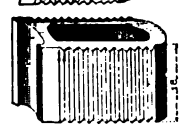
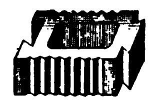


Fig. 595.

Fig. 596.



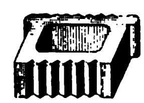


Fig. 597.

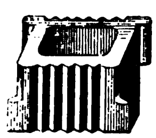


Fig. 598.

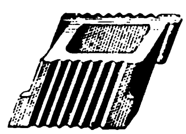


Fig. 599.

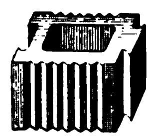


Fig. 600.

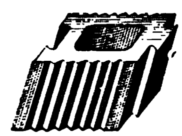


Fig. 601.

Figs. 592 to 601.—Ordinary (Perrusson), Cross-joint (Gilardoni frères), and Dove-tailed (Arthur Metz) "Boisseaux" and "Wagons."

variable; the interior dimensions may vary between 5 inches by 6 inches, and 12 inches by 20 inches, with a length of from 13 to 20 inches. (See table.)

The drying and firing of these products do not present any special difficulty.

Applications.

"*Wagons*" are much used for forming chimney conduits inside walls; this is an interesting and a recent application of pottery to the construction of buildings.

When several conduits are placed side by side they must be bound together, and for that purpose the dove-tailed "*wagons*" (Figs. 590, 600, 601) are to be recommended.

Chimney Tops.—(See roofing accessories, p. 335.)

DETAILS AS TO POTTERY FOR BUILDING.

Internal Dimensions in Centimetres.	Height in Centimetres.	Weight.	Price in Francs.	Remarks.
		"BOISSEAUX."		
		Kil.		
13 × 16	33	6 to 10	0.50 to 0.70	"Boisseaux" are also made 50 centimetres long.
17 × 19	,,	8 to 12	0.60 to 0.85	
16 × 25	,,	15	0.85 to 0.90	
22 × 25	,,	12 to 16	0.85 to 1.00	
25 × 30	,,	16 to 18	1.10 to 1.30	
		VENTIDUCTS.		
Internal Diameter in Centimetres. 13	33	5 to 6	0.35	Catalogue prices subject to reduction.
16	,,	5.5 to 9	0.45	
19	,,	7 to 11	0.55	
22	,,	8 to 13	0.65	
25	,,	9 to 15	0.75	
		"WAGONS."		
		Straight or Oblique Ordinary "Wagons."		
Thickness of the Walls in Centimetres. 25	16.5	8 to 9	0.60 to 0.80	The same remark may be made as above as to prices.
35	,,	9 to 13	0.70 to 0.90	
40	,,	10 to 19	0.80 to 1.00	
45	,,	20	1.10	
50	,,	...	...	
		Straight or Oblique Cross-joint "Wagons."		
,, 35	25	17	1.35	id.
		Straight or Oblique Dove-tailed "Wagons."		
,, 35	16.5	15	0.90	id.

CHAPTER VI.

QUARRIES.

THE custom of paving buildings with plates of baked clay of greater or less thickness, began with the use of brick; that is to say, it dates from the earliest historic period. The Romans, to whom we must always revert when speaking of architecture, used squares of baked clay for their pavements; at Lillebonne squares measuring 16 inches each side have been found; and others of as much as nearly 2 feet have been discovered at Laudunum. These pavements were intended for halls in which many people assembled; special rooms were paved with those magnificent marble mosaics of which we still possess such fine specimens.

Under Roman dominion, the Gaul preserved the customs of his conquerors; but with the decadence of the Empire, and the great troubles caused by the invasion of the Barbarians, other habits prevailed, and the expensive marble was finally abandoned in favour of pottery. Elsewhere will be found the history of those encaustic tiles from which makers in the Middle Ages obtained such beautiful effects. We are only concerned now with red clay squares, which were always manufactured with more or less care in every country. In France, the most admired specimens come from Beauvais, Burgundy, and Provence.

As regards method of manufacture we must distinguish between—

1. Ordinary clay quarries, called native.

2. Choice quarries, of cleaned clay, called Beauvais or Marseilles squares.

1. **Ordinary Clay Squares** (*native quarries*).— These are made

like bricks: by hand or machine; by hand, the clay after being blended, is moulded in square or hexagonal moulds of the required dimensions; then, after having undergone some hardening, the quarries are carefully stamped, returned to dry, and fired in ordinary brick-kilns. With machinery, the process of manufacture resembles that for bricks, except that the stamping must be more carefully carried out, as we shall see in the case of the quarries now to be described.

2. **Smooth Quarries of Cleaned Clay.**—The preparation and choice of clays are of great importance in the manufacture of these squares. Clays which are too poor cannot be used alone,

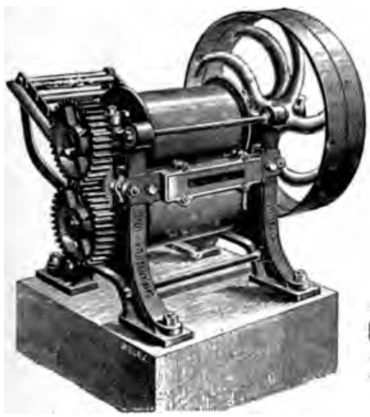


Fig. 602.—Expression Machine for Quarries.

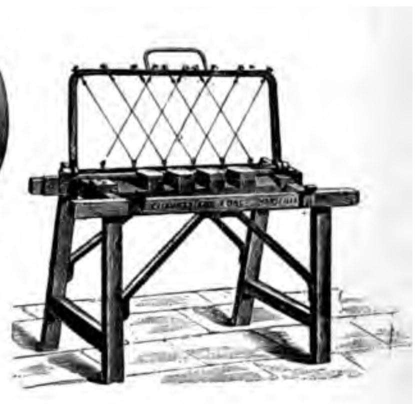


Fig. 603.—Special Cutting-table for Quarries.

and a certain quantity of rich clay must be added. The cleaning is performed under the same conditions as that of the kaolins and with the machinery represented in Fig. 24. The clay thus purified is transmitted to the pug-mill, and then to the expression machine, the die of which has the dimensions of the quarry to be manufactured (Fig. 602).

If the quarries are to be hexagonal, the prism of clay is cut with crossed wires (Fig. 603); the slabs are then piled together, and when sufficiently hardened, are ready for the final work of the press.

The presses used are similar to tile presses; they are worked

by hand and provided with a special system of demoulding. The moulds can be easily changed according to the dimensions

Fig. 604.—Quarry Press (Jäger).

Fig. 605.—Quarry Press (Laeis et Cie.).

QUARRY PRESSES.

Fig. 606.—With Jointed Levers (Bernhardi Sohn).

Fig. 607.—Worked by Steam (Jäger).

Fig. 608.—Worked by Steam (Bernhardi Sohn).

of the quarries to be stamped. Sometimes jointed levers (Fig. 606) are substituted for the compression screw. The presses may also be worked by steam (Figs. 607, 608); they are

provided with two or three moulds which can be emptied and filled during compression.

When stamped, the quarries are dried again, and afterwards undergo polishing by friction between two rollers, one of which is of polished bronze, the other of cast-iron and fluted (Fig. 610).

The upper roller smooths the upper surface of the quarry, while the lower one produces on the other side hollows which will help to increase its adhesion to the mortar. In order to give absolutely uniform dimensions to the quarries, they are cut with hand callipers, or more quickly with a cutting machine

Fig. 609.—Cutting Machine for Quarries.

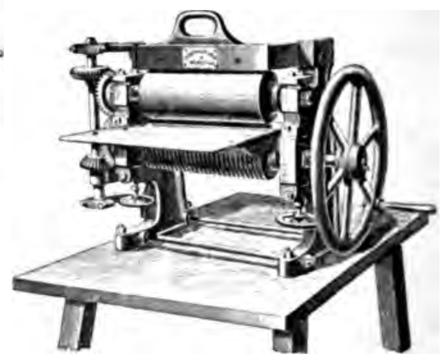


Fig. 610.—Polishing Machine for Quarries.

(Fig. 609), which consists of four or six flexible blades according to the shape required. The section is conical and without seams.

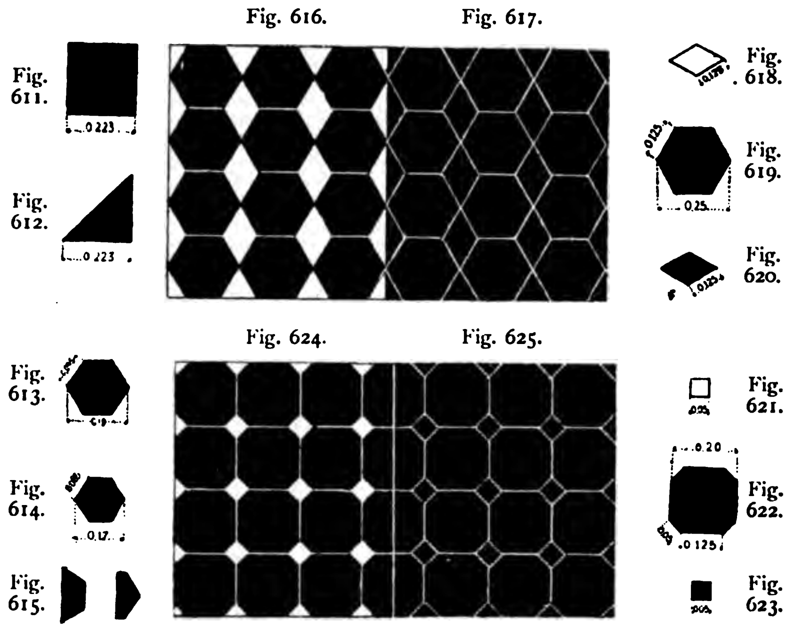
Drying and Firing.—The quarries are placed in pairs with their polished faces against one another, and piles are formed so as to prevent the surfaces from warping, which would certainly occur with quarries of slight thickness.

The firing usually takes place in intermittent kilns. Continuous kilns do not seem to be suitable for this process, which requires a very slow and careful *enfumage*; this must be specially watched on account of the shape of the quarries, and of the contraction which they undergo in baking.

The colour of these paving bricks is usually red, but white ones can be made by a suitable choice of clays, and even black ones can be produced by admixture of oxide of manganese, or more economically by a deposit of coal on the squares when still red ("*encastage*" in presence of powdered coal).

Applications.

The ground to be paved is thoroughly levelled and rammed down, and the quarries are laid on a bed of cement or, more



Figs. 611 to 625.—Quarries and their Applications.

economically, on plaster. The quarries may be square (Fig. 611), hexagonal (Figs. 613, 614), or octagonal (Fig. 622). This latter form is combined with little white (Fig. 621) or black (Fig. 623) squares to produce various patterns of pavement (Figs. 624, 625). In the same way diamond-shaped white (Fig. 618) or black (Fig. 620) are combined with the hexagonal shape (Fig. 619) to give the patterns represented in Figs. 616 and 617.

PARTICULARS OF QUARRIES OF ORDINARY CLAY, CLEANED OR OTHERWISE.

Maker.	Colour.	Shape.	Dimensions.		Weight.	Quantity to the Square Metre.	Price in Francs.		Remarks.
			Side and Thickness.	Inscribed Circle.			Per 1000 (1).	Per Square Metre.	
Boulanger (Auneuil) . .	...	Square	0.16	...	1.350	39	**45**	**1.57**	(1) Catalogue prices, on which a reduction is always made, depending upon the amount of the order. Goods *taken at the factory*.
Gilardoni frères . . .	...	Hexagonal	0.16	...	0.750	41	**40**	**1.64**	
	Red	Square	0.185 × 0.025	...	1.850	...	**70**	...	
	,,	,,	0.22 × 0.025	...	2.175	...	**80**	...	
Lartigue (Auch) .	Red or white	,,	0.095 × 0.023	...	0.300	...	**50**	...	
	Red	Hexagonal	0.115 × 0.022	0.20	1.575	...	**80**	...	
	,,	Octagonal	0.095 × 0.023	0.23	2.075	...	**100**	...	
	,,	Square	0.160	...	1.150	...	**35**	...	
Legros (Dieppe) .	,,	,,	0.22	...	2.400	...	**100**	...	
	,,	Hexagonal	0.16	...	1.100	...	**35**	...	
	,,	Square	0.16 × 0.018	...	1.000	40	**40**	**1.60**	
	,,	,,	0.215 × 0.024	...	2.100	20	**80**	**1.60**	
Tuilerie de Bourgogne (Montchanin) .	White	,,	0.090 × 0.020	...	0.300	20	**40**	...	Goes with octagonal.
	Red	Hexagonal	0.080 × 0.018	0.15	1.800	40	**40**	**1.60**	
	,,	,,	0.120 × 0.024	0.21	1.800	25	**80**	**2.00**	
	,,	Octagonal	0.090 × 0.020	0.21	1.600	20	**80**	**1.60**	
	,,	Square	0.160	...	1.000	40	**50**	**2.00**	
	,,	,,	0.223	...	2.500	20	**90**	**1.80**	
	White or black	,,	0.050	...	0.220	25	**28**	...	Goes with octagonal.
	,,	Diamond	0.125	...	0.330	...	**50**	...	Goes with hexagonal.
Perrusson fils and Desfontaines (Ecuisses) .	Red	Hexagonal	0.085	0.15	0.850	50	**50**	**2.50**	
	,,	,,	0.095	0.17	1.250	40	**90**	**3.60**	
	,,	,,	0.125	0.21	1.800	25	**90**	**2.25**	
	,,	,,	...	...	...	18	**90**	**2.50**	18 white or black diamond-shaped are required.
	,,	Octagonal	0.12 × 0.06	0.20	1.700	25	**90**	**2.95**	25 white or black squares are required.
Société Génerale des Tuileries de Marseille	,,	Square	0.150 × 0.017	...	0.500	44	...	...	These quarries, called *Marseilles ferruginous*, are nearly equal in hardness to quarries of stoneware pottery.
	,,	,,	0.200 × 0.017	...	1.200	25	...	...	
	,,	Hexagonal	0.200 × 0.015	...	0.950	28	...	...	

CHAPTER VII.

TERRA-COTTAS.

History.—Under this name, which is the Italian equivalent of "baked clay," we comprise pottery intended for architectural ornaments, and especially that which contributes to general decoration. The gutter-covers and finials of which we have spoken under the head of roofing accessories, might have been included among terra-cottas, but their fixed location takes from them the special characteristic more particularly attributed to ornamental pottery.

Did this art precede sculpture in stone? Archæologists are not agreed on this point, but it is certain that it is of very ancient date, and we have evidence of this in the numerous cornices, friezes, and bas-reliefs found in the ruins of buildings which were constructed during the early centuries of historic times.

A Greek poetical story or legend attributes to the Corinthian potter Debutades, the invention of moulding, for reproduction in clay, of figures in relief. His daughter loved passionately a young and handsome swain, and, being obliged to separate from him, manifested such grief that her father, in order if possible to mitigate her sorrow, traced the outline of the shadow thrown on a wall by her lover's head; he then filled this silhouette in with prepared clay, and fired the medallion thus obtained in his kiln.

Pliny relates that at the period when Corinth was taken by the Romans, this first remarkable example of a new art was still treasured in the Temple of the Nymphs.

Fragments discovered among the ruins of several Grecian towns show that there was an extensive use of terra-cotta ornaments in Greece, and that the art had reached a high

degree of perfection both in taste and execution. The best work of that period dates from the time of Phidias and Polycletes (5th century B.C.).

The Etruscans, who have left us such remarkable specimens of pottery, borrowed much from the Greeks, while giving their productions an originality of their own. They made friezes and frontons of large size for their temples and buildings.

Rome employed Etruscan sculptors for the decoration of her public buildings, and especially for the Capitol, under Tarquin the Elder (6th century B.C.).

Terra-cotta work held such an important place in Roman buildings, that there existed at Rome a school, the *Collegium figulorum*, for preparing workmen for that industry. The invasion of the Barbarians checked the progress of the arts, and for several centuries the use of terra-cotta, without being completely abandoned, suffered an eclipse. But in the 11th century it once more took a prominent position in architectural decoration, especially in Germany and Italy. There still remain many fine monuments of that period, such as the Carthusian monastery at Pisa (Fig. 317), the cathedral at Créma (Fig. 321), and many others, in which magnificent examples of terra-cotta decoration are found.

The popularity of the plastic art continued until the 16th century; great artists like Bramante and Michael Angelo, did not disdain to use it in the works which they executed, for example the Chancellerie palace (15th century) and the Farnèse palace (16th century, Fig. 328) in Rome, and the apsis of Santa-Maria della Gracia at Milan (Fig. 327). After being again neglected during the two following centuries, terra-cotta was once more successfully utilised in Germany and England in the 19th century. Among the most remarkable examples of buildings constructed of brick and terra-cotta, we may mention the School of Architecture of Schmikel, the Werder Church, and the Museum of Decorative Art in Berlin.

In England, where this kind of work is extensively used, the palatial Natural History Museum recently built in London is entirely constructed, both outside and inside, of iron and terra-cotta

In France, the claims of terra-cotta have been less readily accepted, on account, perhaps, of the abundance of stone in that country; perhaps also through the unreasonable attachment to ancient customs which offers such a stubborn resistance to novelties.

In spite of two brilliant displays, the Exhibitions of 1878 and 1889, which ought to have powerfully recommended the advantages of terra-cotta as applied to modern architecture, its use is still very limited. Nevertheless there were, in those rapidly erected palaces, many happy colouring effects, and many truly original combinations, which lead us to think that this branch of art, if prosecuted and studied by masters, would lead to an architectural renaissance, and that such a renaissance would perhaps rid us of those everlasting façades, which are always the same, and which make our streets so monotonous. May the Exhibition of 1900 settle the question, and finally establish the new architecture of which its predecessors have given us a glimpse!

Manufacture.—The clays should be as pure as possible, and they are selected and mixed in such proportions as will give a paste easily worked and behaving well under drying and firing. They are then subjected to a preparatory treatment, which is more or less thorough according to the quality and degree of finish required: crushing, cleaning, drying, blending, etc. The machines used are the same as those previously described.

The shaping of terra-cottas is performed, by hand, by stamping in plaster moulds.

The paste is divided into fragments called *balls*; sometimes it is roughly shaped into slabs called *crusts*. Balls or crusts are placed in the mould and pressed down with the hand until the clay takes its shape. Care must be taken to compress it evenly, for fear of ruptures in drying and firing.

When the pieces to be manufactured are of complicated form, they are moulded in parts, and the parts are afterwards united. Demoulding is facilitated by the use of moulds in several parts which are taken off separately. Compact pieces are always

hollowed inside to lighten them and ensure a uniform drying. In pieces which are moulded in parts, we must take care that the join does not pass through delicate portions, and for this reason we must study the most suitable form to be given to the moulds.

Pieces which are symmetrical about an axis, such as balustrades (Figs. 653, 654), are made with the potter's wheel. The hollow inside is produced by means of a wooden axis surrounded by a string on which the paste is laid, and the outer surface is formed by means of a calibre cut according to the design of the balustrade.

Drying is carried out in storeyed drying-sheds, which are heated when necessary. Firing is done in various kinds of kilns, which are sometimes specially constructed when the pieces are of exceptional dimensions, such as the pyramids of the grand entrance of the Palais des Arts Libéraux at the Exhibition of 1889. These fine products, designed by the talented sculptor Michel, were executed by the ceramist Muller. One of them, Labor, is represented in Plate II.

Applications of Terra-cotta.

It would be presumption on our part to point out the best way of applying terra-cotta to the decoration of public buildings and private houses; this must be left to the talent of the architects and engineers, and talent is not to be advised. It will be interesting, however, to recall the excellent remarks of M. Paul Sédille, the eminent architect, who, by his pen, by his words, and, better still, by his original work, has done so much to extend the use in France of terra-cotta for architecture.

[1] ". . . The use of decorative pottery requires close care. Very accurate and well-made machinery is required, for decorated clays are usually combined with other materials of definite and small dimensions, such as building-bricks, and this multiplies

[1] Extract from a letter addressed by M. Sédille to M. Lœbnitz, reporter to the jury of Class 20 (Pottery) at the Exhibition of 1889, and published in the latter's report.

apparatus indefinitely. We must also calculate the contraction of the pieces sufficiently exactly, taking into consideration the clays used, to arrange for the necessary space to be left in the building. . . .

" . . . If reliable ceramists could guarantee us to-day perfect pieces, that would not be enough. We must also know *how to use them, mingle them skilfully with other materials, and, above all, combine in one harmonious gamut the powerful colourings of enamels.* There lies the difficulty of this modern assemblage of many colours, which should, by entrancing his eyes, convince the most obstinate of its beauties. I have many times tried to say all that I felt on this question,[1] and how enamels should be used. I do not propose to revert to this here, I merely urge that the poor use sometimes made of enamels should not discourage us from benefiting by the infinite resources and marvellous results which may be expected from them."

It would be difficult to speak more pertinently.

For the sake of clearness, terra-cottas will be divided into three classes, according to their special applications.

1. Terra-cottas intended especially for buildings, including—

(*a*) Those employed on the exterior: balustrades, lintels, pilasters, capitals, friezes, cornices, frontons, pinnacles, and inlayings, such as medallions, metopes, panels, polished stones, rosework, etc. etc.

(*b*) Those used in the interior: ceiling and chimneypiece-rosework, etc.

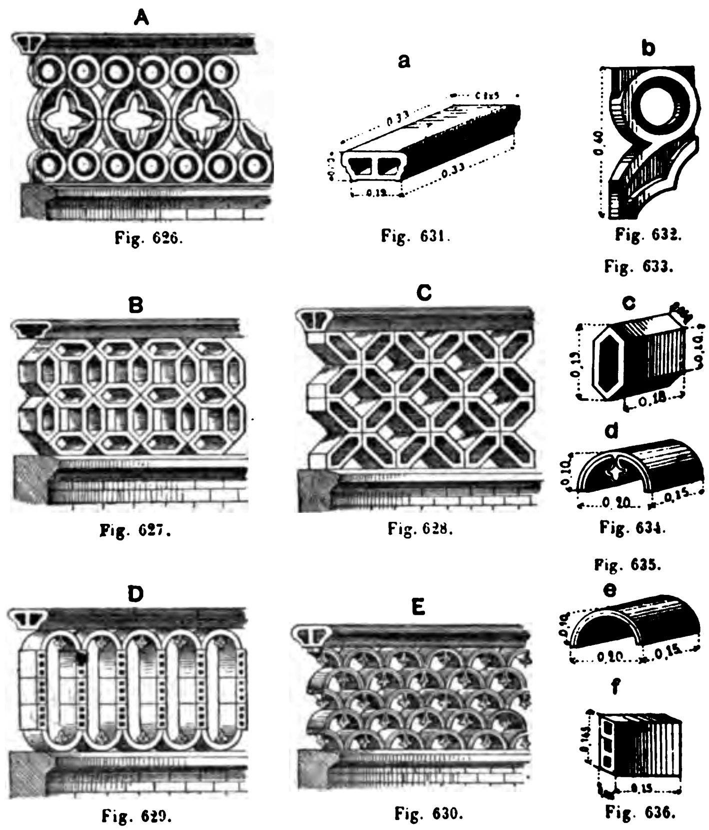
2. Terra-cottas which have less direct connection with architecture, such as garden borders, vases, statues, etc.

Balustrades.—These are composed either of a certain number of simple parts connected together, or of a small number of large ones, reduced sometimes to one single one. The first case is represented by the balustrades A B C D E (Figs. 626 to 630), which are formed, the balustrade A (Fig. 626) by the element *b* (Fig. 632), the balustrades B and C (Figs. 627 and 628) by the element *c* (Fig. 633), arranged in two different ways; the

[1] See the pamphlets of M. Sédille on the use of terra-cotta in architecture (*Bibliography*).

balustrade E (Fig. 630) by the element *d* (Fig. 634), and finally the balustrade D (Fig. 629) by the two elements *d* and *f* combined (Figs. 634, 636). The hand-rail of these balustrades is formed of hollow bricks with two holes of special shape (Fig. 631).

Balustrades are sometimes made up with the classical



Figs. 626 to 636.—Various Balustrades (Perrusson).

baluster, the shape and dimensions of which are easily changeable (Figs. 653, 654, 658, 659).

The second type of balustrade is quite different in appearance from the first; it is applied to various styles, and can be much diversified according to the inspiration and taste of the artist. Sometimes these balustrades are made of a single piece forming pedestal and support (Figs. 648, 652), sometimes they are

formed of ornaments or panels with stone support and pedestal (Figs. 676, 678, 681).

The balustrades of the buildings of the Exhibition of 1889, executed by Lœbnitz (Fig. 687), were fixed to the masonry of the wall against which they rested, the whole being thus rendered very solid.

TERRA-COTTAS BY MULLER.


Fig. 643.

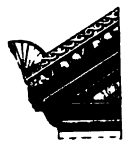


Fig. 644.


Fig. 645.

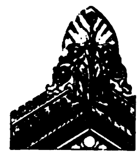


Fig. 646.


Fig. 647.


Fig. 648.


Fig. 649.


Fig. 650.


Fig. 651.


Fig. 652.


Fig. 653.


Fig. 654.


Fig. 655.


Fig. 656.

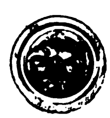


Fig. 657.


Fig. 658.

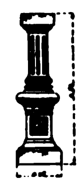


Fig. 659.

Figs. 644, 645, and 646 represent the details of the fronton of the Pavilion of the City of Paris at the Exhibition of 1878, afterwards rebuilt on the Champs Elysées, and demolished in 1897.

Openings.—Doors and windows may receive most varied terra-cotta ornamentation, such as lintels in the form of friezes, decorated pieces forming key-stones (Fig. 682), frames surrounding the whole opening (Figs. 665, 669), or simply knobs more or less richly sculptured (Fig. 680). Besides which, windows often receive ornamented panels forming sills, etc.

TERRA-COTTAS BY LŒBNITZ.

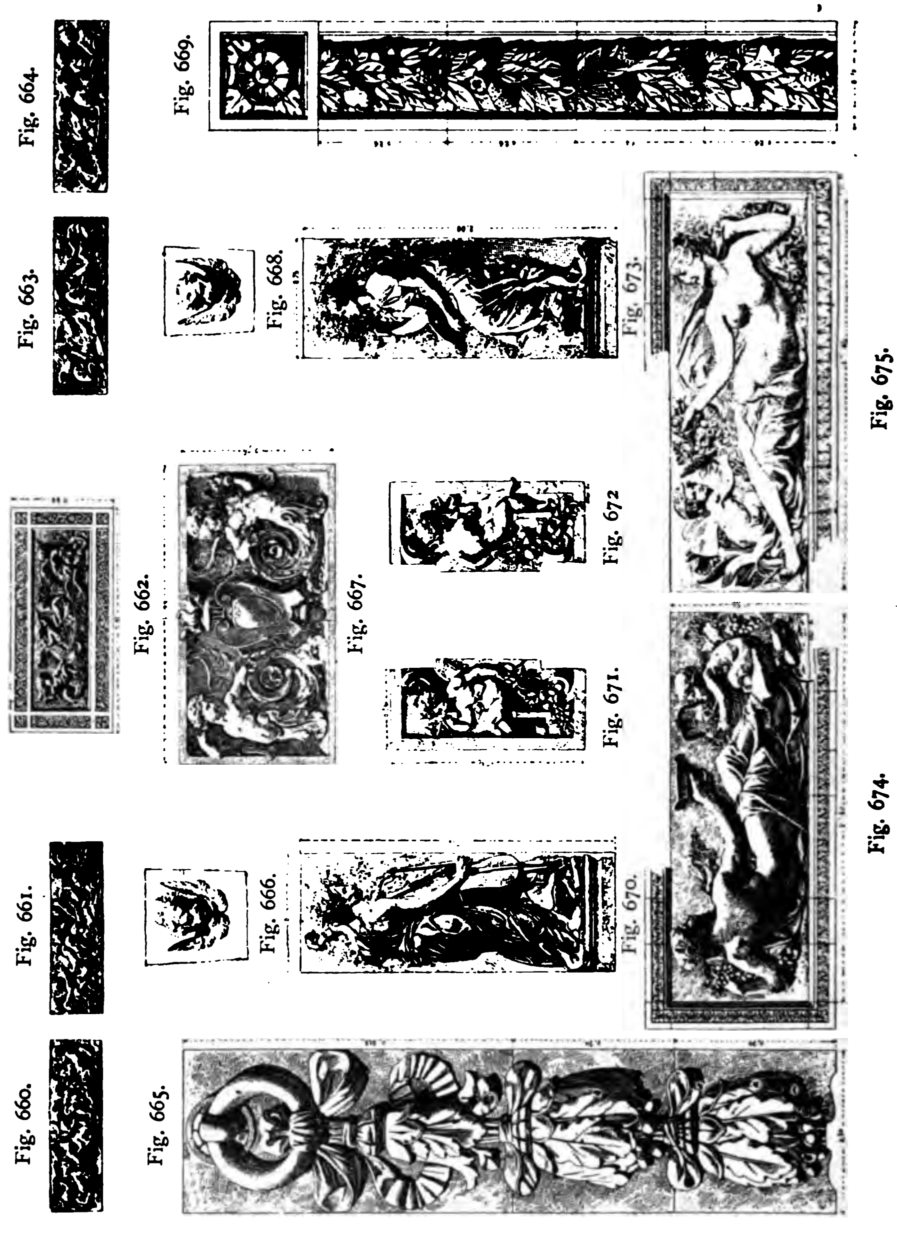


Fig. 660. Fig. 661. Fig. 662. Fig. 663. Fig. 664. Fig. 665. Fig. 666. Fig. 667. Fig. 668. Fig. 669. Fig. 670. Fig. 671. Fig. 672 Fig. 673. Fig. 674. Fig. 675.

Figs. 660 to 664 were designed by Barrias. Fig. 665 represents a door-framework of the Café Soufflet on the Boulevard Saint-Michel.

Columns, Pilasters, and Capitals.—The use of terra-cotta in these pieces offers great opportunities for copying antique patterns (Figs. 649, 651), and also for original work.

Friezes, Frontons, etc.—Friezes and frontons are perhaps the most extensively used terra-cotta ornaments, and they are made in all styles: simple, original, with human figures or allegorical designs (Figs. 660, 661, 662, 663, 665, 667), etc. The same may be said of frontons; Figs. 644 to 646 represent

Fig. 676.

Fig. 677.

Fig. 678.

Fig. 679.

Fig. 680.

Fig. 681.

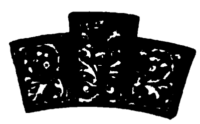


Fig. 682.

Figs. 676 to 682.—Terra-cottas by Villeroy and Boch (Mettlach).

those executed by Muller for the pavilion of the city of Paris at the Exhibition of 1878. They are formed of a larger or lesser number of pieces according to their magnitude.

Friezes are either fixed to the masonry, or supported by other means, according to circumstances. The "Frise des Enfants" at the Exhibition of 1889 (Fig. 684) was held by iron rods which were fixed into the terra-cotta and connected by rivets to the metallic framework.

TERRA-COTTAS EXECUTED BY LŒBNITZ FOR THE PALAIS DES BEAUX-ARTS ET DES ARTS LIBÉRAUX AT THE EXHIBITION OF 1889.

Fig. 684.

Fig. 685.

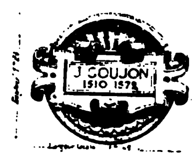


Fig. 686.

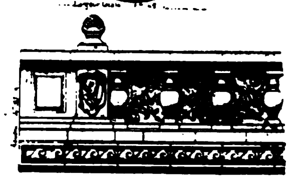


Fig. 687.

Fig. 688.

Fig. 684.—Frise des Enfants. Fig. 685.—Porch Medallion. Fig. 686.—Terra-cotta Frieze with Gold Ground.
Fig. 687.—Balustrade on the First Floor. Fig. 688.—Terra-cotta Design with Gold Ground.

Friezes, cornices, etc., can also be made of small parts. The firm of Gilardoni Brothers has reproduced the principal types of decorated bricks in use in the 14th and 15th centuries in Italy, the South of France, and Germany. Figs. 692 to 697 show some of these elements, and Figs. 689 to 691 the applications which can be made of them.

It is to be hoped that this reproduction will be followed by

Fig. 689.

Fig. 690.

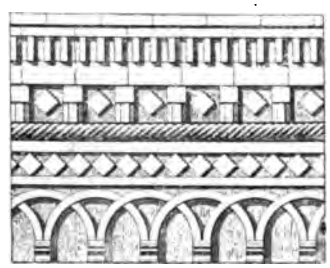


Fig. 691.

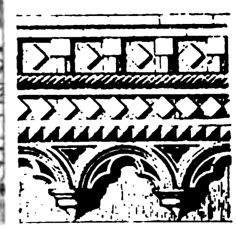


Fig. 692.

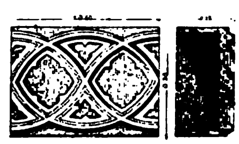


Fig. 693.

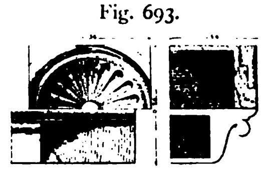


Fig. 694.

Fig. 695.

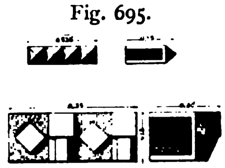
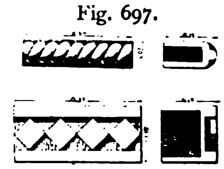


Fig. 696.

Fig. 697.



Figs. 689 to 697.—Specimens of Decorative Pottery (Gilardoni frères).

the manufacture of new types, harmonising with our modern tastes.

Pinnacles are made of pottery in the most varied styles: they may depict animals, bunches of flowers, and all kinds of patterns, according to the purpose of the building.

Medallions, Panels, Rosework, etc.—It is from these that the architect draws largely for decorating buildings. All forms, all types, all styles, may be put under contribution, and, what is still more interesting, the artist of talent may easily invent new

models which will give his work a personal character, and create novelties instead of repeating the commonplace.

The roses of various forms and sizes (Figs. 655, 657), the round medallions (Figs. 643, 647, 685), the panels (Figs. 656, 667, 670, 673, 674, 675), the scrolls (Fig. 680), and knobs, are so many opportunities of decoration placed at the disposal of the architect. The porch of the Palais des Arts Libéraux at the Exhibition of 1889, was adorned with magnificent panels representing figures designed by Michel (Plate II).

(*b*) In the interior of buildings we find numerous applications

TERRA-COTTA CEILING (Perrusson).

Fig. 698.

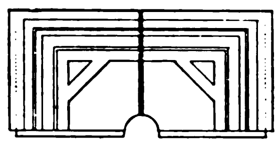
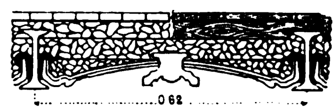


Fig. 699.



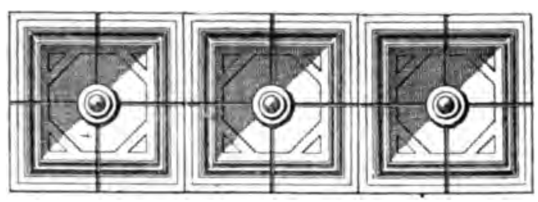


Fig. 700.

Fig. 698.—Panel. Fig. 699.—Section of Ceiling. Fig. 700.—Application.

of terra-cotta, especially in ceilings supported by I-shaped iron girders. These ceilings are formed of panels of various shapes and dimensions, and more or less decorated. The arrangement of the panels depends entirely upon the taste of the architect. Figs. 698, 699, and 700 show a simple arrangement; the panel is composed of two parts (Fig. 698), with overlapping join and resting upon the I-shaped iron bars; in the middle is a rose. When complete, the ceiling is as shown in Fig. 700.

Unpolished terra-cotta may also be used for making very pretty chimneypieces for rooms in plain (Fig. 864) or decorated style as desired.

2. With regard to terra-cottas such as garden borders, vases and flower-stands, and statues, they belong, with the exception of the first-named, to the domain of artistic and sculptural pottery, and have only a distant connection with architecture proper.

APPENDIX.

Official Methods of Testing Terra-cottas.[1]

Specimens.—Tests of terra-cottas should always be made on marketable products.

If it is desired to know as precisely as possible the value of a manufactured article, it is better to work upon specimens at different stages of firing. It is often sufficient to examine the most slightly baked specimens, which will be easily recognised by their appearance, and especially by their being less hard and of slightly greater dimensions than the average.

General Rules.—The trade mark of the specimens shall be noted, their shape, the state of their edges and surfaces, also their colour.

In the case of bricks and quarries, their length, breadth, and thickness shall be measured. In the case of tiles, their length and breadth shall be measured, and sketches or sections shall be drawn which shall indicate, in a sufficiently clear manner, the hollows and projections as well as any fitting arrangements that the specimens may possess. Finally, for pipes, the internal diameter shall be measured, the effective length not counting the socket, the thickness of the walls, as well as the shape and arrangement of the socket, if any.

The dimensions of bricks and tiles should be verified, and should be identical for similar pieces; any differences exceeding 1 per cent. shall be noted.

When the laboratory has at its disposal a sufficient number of specimens from the same factory, it will be advisable to measure on the one hand those most baked or the smallest, and on the other hand those least baked or the largest. The observed differences, if any, shall be noted.

PHYSICAL TESTS.

1. *Observation of Structure or Homogeneousness.*—The observation of structure or homogeneousness shall consist of the examination of a fracture with the naked eye or a magnifying-glass.

There shall be noted—

(*a*) The appearance of the fracture, whether full-grained and with more or less pronounced toothings, or smooth or of conchoidal surface.

(*b*) The coarseness of the grain, stating, according to the classification adopted for natural building-stones,

[Very fine grains (.2 mm. to .4 mm.), fine grains (.3 mm. to .8 mm.), fairly fine grains (.5 mm. to 1.2 mm.), medium grains (1 mm. to 2.5 mm.), rather coarse grains (2 mm. to 4 mm.), coarse grains (3 mm. to 7 mm.), very coarse grains (5 mm. and above).]

whether the grain is fine, medium, or coarse, and if it is uniform or of varied dimensions.

(*c*) The homogeneousness, by observing whether the mass is entirely, partly, or slightly homogeneous, whether there exist more or less numerous and more or less accentuated planes of exfoliation or cleavage.

[1] These methods were adopted in 1895 by a Commission nominated by the French Government.

2. *Specific Gravity.*—The determination of the specific gravity of the substance shall be made from the powder of pulverised fragments passed through a sieve of 900 meshes.

The powder shall be dried at a temperature of + 110°.

The specific gravity shall be determined by means of volumetres, by one of the methods now used, so as to obtain the first decimal figure with certainty and the second with an approximation of two units.

The liquid used shall be benzine or mineral essence.

The temperature should remain constant during the whole operation; it should not exceed + 15°.

3. *Apparent Density.*—The determination of apparent density should be made, as much as possible, with specimens which have remained intact, after desiccation at a temperature of + 30° to + 40° C.

When the specimens have a regular geometric shape which allow of the volume being determined by measurement, a sliding-scale approximating to tenths of a millimetre shall be used; the weight shall be determined by means of a balance sensitive to half a centigramme.

When the specimens are of irregular shape, or present re-entrant angles, the volume, and thence the apparent density, shall be determined by finding the difference between its weight in air and in water. Care shall be taken beforehand to coat the surface with a varnish capable of preventing the entrance of water. A thin layer of melted tallow applied with a brush and spread with the finger fulfils this condition very well.

4. *Absolute Porosity.*—The absolute porosity shall be deduced from the difference between the specific gravity and the apparent density.

5. *Relative Porosity, or weight of water absorbed in a given time.*—The determination of the weight of water absorbed, shall be made with a series of at least three specimens previously dried either in the open air or in a stove at a temperature of + 30° to + 40° C. It is advisable as much as possible to work with whole specimens and not fragments.

After drying, the specimens shall be immersed in water to the depth of half their thickness for twelve hours, then completely submerged either for twelve hours, thirty-six hours, seven days, or twenty-eight days.[1]

If the specimens contain an appreciable amount of lime, of magnesium, or of soluble salts, it will be advisable to repeat the experiment once or twice on the same specimens.

The quantity of water absorbed, or the relative porosity, should always be calculated by volume, but the percentage of water by weight shall also be noted.

Special Arrangements for Tiles.—As regards tiles, the Committee expresses the wish, as in the case of roofing slates, that experiments should be made to find out what quantity of water can be absorbed by a square metre of tiles, fixed just as they really are in practice upon a frame inclined at the minimum angle adopted for roofs, by subjecting this frame to a regular shower of known intensity for a given time.

Perviousness. — Tiles. — The test shall be made with at least three whole tiles which have been previously immersed for forty-eight hours, as described in § 5. A glass tube of .035 mm. internal diameter and .11 height shall be placed horizontally and fixed with pure cement at about the middle of the upper surface of each tile. The tube, closed at the top by an indiarubber cork, shall be put into communication with a reservoir giving a head of water of .1 m.

By means of a reservoir placed under the lower surface, the water passing through each tile shall be collected.

The perviousness shall be estimated by the volume of water which has passed through in an hour, after the experiment has been continued for twenty-four hours.

[1] In the case in which the time of immersion is to exceed forty-eight hours, if it is wished to shorten the experiment, use may be made of the process of imbibition by means of the exhausted receiver, as described for tests of natural building-stones (Note of the Commission).

7. *Tests of Resistance to Frost.*—The test of resistance to frost shall, as much as possible, be made upon whole products. The trial can, however, be made with fragments. In this case, the cut or broken parts of the specimens should be protected by a varnish or a thin coating of tallow, in order to leave free for the penetration of water only those faces usually seen.

The correct tests of resistance to frost, carried out as directed in the case of natural stones, shall comprise—

In making these trials, note must be taken of the following details:—

1. For the immersion, distilled water at a temperature of +15° to +20° C. shall be used, or, in default of distilled water, drinking water at the same temperature, which presents no inconvenience when it is not required to determine the quantity of soluble salts.

2. The specimens shall be exposed to a temperature of −15° to −20° C.

3 The duration of exposure to the cold shall be four hours.

4. Thawing shall be effected by complete immersion of each specimen in distilled or drinking water at a temperature of +15° to +20°. (In the case of natural stones, a volume of 500 cubic centimetres is prescribed for a specimen containing 7 cubic centimetres.) For specimens tested in a state of imbibition after an immersion of twenty-four hours, the thawing is effected in damp air and not in water. During the interval separating successive freezings and thawings, the specimens are kept in closed jars to prevent a too great loss of the absorbed water; care is moreover taken, before subjecting to cold again, to plunge them into water for a few moments so as to keep them, during the whole test, in about the same state of imbibition as that in which they were at the beginning of the experiment.]

(1) The examination of the specimens with a magnifying-glass, with a view to ascertaining whether cracks or splits have occurred in those products which have been subjected to successive frosts and thaws twenty-five times.

(2) The determination of the loss of weight of the frozen specimens.[1]

There must be used for these tests at least—three specimens soaked in water for twenty-four hours; three specimens saturated with water.

MECHANICAL TESTS.

1. *Resistance to Rupture by Crushing—Bricks and similar Materials.*—The test of resistance to rupture by crushing shall be made on pieces of nearly cubical shape, obtained, for example, in the case of ordinary bricks, by placing two half bricks one over the other and binding them together by a thin layer of pure Portland cement.

The surfaces of compression shall be rendered exactly parallel by a coating of similar aste.

As in the case of natural building-stones, the tests of resistance to crushing shall be made with lever apparatus or hydraulic press.

The objects should be placed between the compressing plates, covered by a sheet of thin pasteboard; it is advisable that one of the two compression plates should be movable in every direction.

The dimensions of the surfaces exposed to pressure shall be noted in the report of the experiment at the same time as the resistance offered per square centimetre.

The test shall be made upon at least three objects from the same specimen.

The average of the results given shall be calculated.

It will be well to make the test with two series of objects, one in the dried state, the other in a state of imbibition, the degree of imbibition being noted.

2. *Resistance to Rupture by Flexion—Bricks.*—The test of resistance to rupture by flexion shall, in the case of ordinary bricks, be made with whole products placed upon

[1] If the specimens have borne without deterioration the tests of resistance to frost, it will be advisable to compare the resistances of those specimens to compression and flexion, after another desiccation, with those of specimens of the same origin which have been subjected to the same pressure after drying, but without having been submitted to the action of frost (Note of the Commission).

two knives .2 metres apart, and loaded at the middle gradually until rupture occurs.

The gross weight which determines the rupture of each specimen shall be noted.

Products greater in length than ordinary bricks (floor bricks) shall be tested with a bearing-space between the two supporting knives equal to that usually given in practice.

Tiles.—The tests of resistance to rupture by flexion shall be made upon whole tiles placed upon two knives, and loaded at the middle gradually until rupture occurs.

When the tiles have not a rectilineal section, small transverse horizontal ridges of pure Portland cement and 1 centimetre broad shall be placed in a line with the supports and the middle of the knives, with the object of levelling the undulations and dividing the pressure uniformly over the whole width.

One of these ridges shall be placed at the point where, in roofing, the tile is to rest upon the laths, and the other at the point where it rests upon the tile below.

The load which produces rupture shall be noted.

It will be advisable to make the test with tiles which have been soaked in water, the degree of imbibition being noted.

3. *Resistance to Wear by Friction.*—The determination of the resistance to wear by friction shall be made under the same conditions as in the case of natural building-stones, both as regards the dimensions of the object tested and the test itself.

[To determine the resistance to wear by friction, the quantity of the specimens worn away shall be measured, when they are subjected, under a given pressure, to the friction of standard sand spread uniformly over a circular horizontal cast-iron track which moves with known speed.

The specimens shall have the dimensions: .06 m. by .04 m. base and a variable height of from .10 m. to .12 m.; they shall be placed in pairs on opposite sides of the axis and on the same diameter of the grinding-mill, in such a way that their centres shall be on the circumference of a circle of radius .261 m., the lesser dimension being in a direction perpendicular to the radius.

The total pressure on the friction plane shall be 250 grammes per square centimetre.

The standard sand used shall be obtained by pounding, and then sifting, medium hard Fontainebleau quartz sandstone, passing through a No. 50 sieve (324 meshes) and retained completely on No. 200 sieve (4900 meshes).

The quantity of sand to be spread upon the grindstone shall be one litre per specimen and per thousand turns of the mill.

The machine shall be turned at the rate of 1000 turns per half-hour, and the specimens shall be subjected to 4000 turns of the mill. The diminution in the height of the specimen shall be measured, and the loss of weight determined. Similar notes shall be made during the course of the test after 1000, 2000, and 3000 turns.

The specimen may be turned over after 2000 turns of the mill, in order to compare the results obtained on the upper surface and the lower surface.]

4. *Resistance to Rupture by Shock.*—The experiments now being carried out do not yet allow of rules being laid down for this test.

These experiments should be continued.

5. *Resistance to Rupture by Internal Pressure—Special Tests for Pipes.*—The tests of resistance to rupture by internal pressure shall be made either with a force-pump or a hydraulic accumulator.

The unit of pressure to be adopted is a kilogramme per square centimetre, and the numbers, unless otherwise stated, refer to effective pressures.

The pipes to be tested should be exactly filled with water. It is important that the pressure should be exerted upon them gradually and without shock. The manometre should indicate without risk of error the pressure acting within the pipe.

The test can be made with a single pipe or several pipes combined.

The joints closing up the ends of the pipes should be arranged so as not to leak, and should be made in such a way that the fixing of them shall not cause a premature rupture of the pieces being tested.

The Committee expresses the wish that the experiments now being carried on with

a view to finding a convenient closing arrangement for the ends of pipes will be continued.

CHEMICAL TESTS.

1. *Test for Lime and Magnesium.*—With the object of determining whether, in terra-cottas, there exist lime or magnesium caustic, five specimens shall be immersed in boiling water for three hours, and it shall be noted whether, under these circumstances, exfoliations are produced.

2. *Determination of Soluble Salts.*—To determine the proportion of soluble salts that a terra-cotta may contain, five specimens shall be taken, chosen in preference from the middle of the terra-cottas, and they shall be pulverised so as to make them pass entirely through a sieve of 900 meshes; 25 grammes of the powder thus obtained shall be taken, and boiled for an hour in 250 grammes of distilled water, the evaporated water being replaced. After filtering, the liquid shall be entirely evaporated, and the residue obtained shall be weighed.

PART II.

MADE-UP OR DECORATED POTTERY.

CHAPTER I.

GENERAL REMARKS ON THE DECORATION OF POTTERY.

THE pottery of which we have spoken in Part I. has no decoration; Salvetat called it *simple pottery*. Part II. is devoted to what the same author called *made-up pottery*; it is distinguished from the former kind by its decoration.

A decorated piece of pottery is one whose surface receives an earthy, vitreous, or metallic coating, which modifies its appearance and gives it new properties; the decoration may be reduced to a simple engobage, or be composed of brilliant colours, like the magnificently painted panels with which walls are covered.

The different methods of decorating pottery comprise decoration with *engobes*, or dips with *glazes*, with *colours*, or with *metals*.

Decoration with *engobes* is effected by means of white or coloured earthy matters with which pottery is totally or partially coated, so as to modify its colour and its appearance, to give it sometimes new properties with a view to applying a glaze, or finally to produce decorative effects by using variously coloured engobes.

Decoration with *glazes* is effected by means of vitreous or opaque, coloured or colourless substances, which are fixed by fire to the pottery to render it impervious, give it a brilliancy which will enhance its colouring, or on the other hand hide or mask that colour when it is not an agreeable one.

Decoration with *colours* is effected by applying to the pottery metallic oxides, mixed or not with vitrifiable substances and fixed under or over a glaze. The effect produced is very different from that produced by enamels, and permits of our distinguishing them, although they are often confused together.

Decoration with *metals* is obtained by applying them according to the effect required, either in the metallic state, when we wish to produce the effect called metallic lustre, or in the form of salts.

Having given these definitions, we can now study in detail the various styles of decoration.

Engobes, or Dips.

Engobes are either white or coloured. When white, they serve to modify the colour of the pottery to which they are applied. They are made of fine white earths, to which are added a thinning substance and different salts. Their composition should be such that, when applied to the paste, they shall bear the same firing, undergo the same dilatation, behave in the same manner under the influence of the atmosphere of the kiln, and finally adhere satisfactorily to the paste. The engobe is laid on by diluting to a state of paste the mixture of the proper ingredients, and dipping the object which has to be coated, in this paste, or else, by pouring the liquid engobe over the paste, or finally, by applying it with a brush.

Coloured engobes are used for the same object as white ones, or, as is more frequent, for obtaining decorative colouring effects. They are produced from earths which have been naturally or artificially coloured by the addition of metallic oxides to white or only slightly coloured earths.

In the first case, the coloured engobes are applied like the white one; it is an economical method of giving to a paste a colouring, or properties which it would be too costly to communicate to it in any other way.

In the second case, the engobe is used in two different ways: diluted with water like a water-colour, it is applied with a brush to the piece when unbaked or slightly warmed; after drying, it is fired as it is if the colour is to remain dull, or it is covered with a glaze; this mode of decoration, which is called *peinture à la barbotine*, always gives dull tones and not very varied effects.

The other method of applying coloured engobes consists of making hollows in the object to be covered, which are filled with a thick paste of the engobe. Several engobes of different colours can be applied to the same piece. It is allowed to dry, and the surface is then cleaned in order to bring out the designs; this is the process employed in making paving quarries, in imitation of those of the Middle Ages. If the engobe reaches a certain degree of thickness, it is called incrustation.

The Greeks and Romans used extensively engobes made with white, red, and yellow clays, to decorate their vases. By these simple and primitive methods they have produced masterpieces which we now admire in our museums. These coatings are dull, except the black one, which shines in consequence of the iron contained in it.

To-day engobes are seldom used alone, and the *peinture à la barbotine* is scarcely used at all except for architectural pottery. In most cases they are covered with a glaze; their composition must therefore be allied with that of the glaze. They are applied to the pieces when unbaked or slightly warmed.

Glazes.

These are complex metallic silicates of variable composition; they are usually divided into:

Soft glazes, *colourless* and *transparent* vitreous substances, fusible at a fairly low temperature and generally containing lead;

Hard glazes, also *colourless* and *transparent*, but melting at a high temperature and containing always an earthy or alkaline-earthy substance;

Enamels, *coloured* vitreous substances; these are divided into *transparent enamels*, which are plumbiferous or alkaline, and *opaque enamels*, which are generally stanniferous and are used especially in the manufacture of faïences;

Colours, metallic oxides generally mixed with vitrifiable substances; they are either laid direct upon the pottery and afterwards covered with a colourless glaze—this is the *under-glaze*

decoration—or upon the glaze itself, which is the *over-glaze* method.

These subdivisions are clear enough; nevertheless more precision may be given to the terms employed by adding to the name of the glaze those of the principal substances which enter into its composition; we say, for instance, plumbiferous glaze, calcareous glaze, stanniferous enamel, etc.

Composition of Glazes.—The foundation of glazes is silica, which forms, in combination with other basic substances, fusible and transparent multiple silicates which are really glasses.

Certain bodies which enter into the composition of these glasses are called *fluxes* because they have the property, when mixed with other substances, of rendering them fusible if they were infusible, or of increasing their fusibility if they were already fusible. Fluxes are not necessarily fusible themselves. Lime and alumina are infusible, but the result of their mixture in certain proportions with silica, itself infusible, is the formation of fusible compounds. It is not always easy to determine which body it is which acts the part of flux to the other. Moreover, it has been shown that multiple silicates are more fusible than simple ones.

In coloured glazes, the vitrifiable substances are mixed with colouring metallic oxides; hence we have two series of compounds to study.

1. **Vitrifiable Substances Entering into the Composition of Glazes.** — ACID SUBSTANCES. — *Silica* (SiO_2) *and Silicates.*— These are introduced in the form of *white sand*, used without any preparation, and of *quartz* and *flint*, which must be calcined and crushed.

These substances, in spite of their practically similar chemical composition, do not produce the same effect. Sand from one place would not take the place of sand from another; for instance Fontainebleau sand is less fusible than that from Nevers, and flint is more fusible than Fontainebleau sand.

Alkaline silicates are only used in special cases. Among the silicates of alumina, those most used are the felspar and the non-ferruginous pegmatite; they enter into the composition of

porcelain glazes and glazes for the faïences called *flint-ware.*

Kaolin and *white clays* enter also into the composition of glazes; they diminish fusibility and give an opaline transparency.

Boric acid (BoO_3H_3) and borax (borate of sodium, $Bo_4O_7Na_2$, $10H_2O$).—The latter contains much water of crystallisation, and it must be calcined before use. The boracic glazes are hard and brilliant; at a high temperature they dissolve the metallic oxides and transform them into transparent enamels.

BASIC BODIES.—*Alkalies and Alkaline Salts.*—The alkalies are more used in the form of *carbonate of soda* (CO_3Na_2, $10H_2O$) or of *potassium* than in the free state. They dissolve the metallic oxides and give enamels a purity and transparency which no other fluxes obtain.

Among other alkaline salts: the *chloride of sodium* (NaCl) is frequently used in the preparation of the stanniferous enamels, which it purifies by dissolving all the impurities; applied to stoneware (salting), it gives it a brilliancy which does not make them sticky and which cannot be obtained by any other method. The *nitrate of potash* (KNO_3) is decomposed at a dull red temperature setting free oxygen; this property is utilised for freeing frits from the organic impurities contained in them. It enters also into the composition of some enamels. In *cryolite* (double fluoride of sodium and aluminium) we have a means of introducing soda and alumina simultaneously into the glaze, for this body is decomposed at a red heat into these bases and into volatile fluoride of silicon. The glaze must then be silicious.

ALKALINE-EARTHY DERIVATIVES. — The *carbonate of lime*, $CaCO_3$ (chalk), and the *sulphate of lime*, $CaSO_4$, $2H_2O$ (gypsum), form with silica, silicates which are not very fusible, but with borax they give glazes which are more fusible, and which are used for flintware and stoneware.

The *fluoride of calcium*, Fl_2Ca (fluor spar), is sometimes used as a flux for pottery fired at a high temperature.

DERIVATIVES OF LEAD.—The *protoxide of crystallised lead*, PbO (litharge), and its product of oxidisation, *plumbate of lead*

(minium), are used in many glazes, being the more fusible because they are rich in lead.

The *carbonate of lead*, $PbCO_3$ (white lead), is also used for introducing lead into glazes.

As for the *sulphide of lead*, PbS (galena), it is in general use for the glazing of common pottery.

The *oxide of bismuth* (Bi_2O_3) acts like oxide of lead, but gives still more fusible silicates.

DERIVATIVES OF TIN.—*Stannic oxide*, SnO_2 (tin putty), is the base of the opaque enamels, for it remains in suspension and does not dissolve in the vitreous substances; it is generally associated with oxide of lead. This mixture, called *calcine*, is prepared by calcining tin and lead together in a reverberatory furnace.

The *oxide of zinc*, ZnO, is sometimes used as an opaque body in silicious glazes; the same may be said of *phosphate of lime*, $(PO_4)^2Ca_3$.

2. **Colouring Substances Entering into the Composition of Glazes.**—These are generally metallic oxides, sometimes salts, and more rarely the metals themselves.

The table on p. 390 shows the principal colours obtained, under different conditions, with the metallic derivatives either single or mixed.

PREPARATION OF GLAZES.—This comprises the pulverisation of the substances and the mixture of the powders so obtained. The crushing is effected dry or wet in various machines, mills, or cylinders, care being taken that there is no contact between the iron and the substances to be crushed. The grindstones, which are generally of hewn flint, are enclosed in an oak trough; they may be worked by hand (Fig. 704) or by steam (Fig. 702) or so made as to be worked in either way (Fig. 703). When the crushing is believed to be effected, the stopper is removed and the liquid mixture allowed to flow out. The crushing of the colouring substances which enter into the composition of coloured glazes is performed with grinding mills (Fig. 704).

The insoluble bodies in the water are subjected to direct crushing, but the soluble bodies (alkaline carbonates, boric acid,

borax, etc.) must first be transformed into silicates or insoluble borates by *fritting* or *vitrification*.

Fritting is effected by heating the soluble substances in a

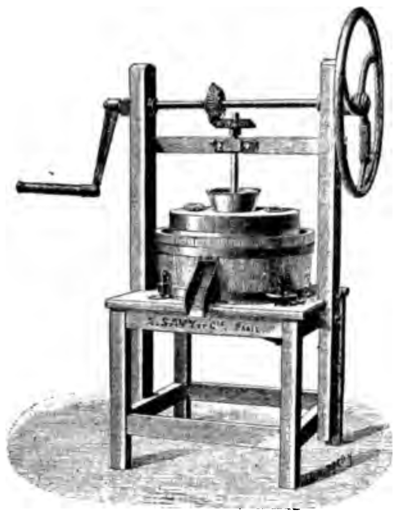


Fig. 701.—Hand-worked Glaze Mill.

Fig. 702.—Glaze Mill, worked by Steam.

Fig. 703.—Glaze Mill (Laeis et Cie.).

Fig. 704.—Grinding Mill.

crucible or on the floor of a kiln with other insoluble substances which enter into the glaze; under the influence of heat these different bodies cohere and form a mass, which is then pulverised. If the heating is pushed further, the substances melt into a glass,

	Mixed with	Antimony.	Chromium.	Cobalt.	Copper.	Iron.	Manganese.	Nickel.	Tin.	Zinc.
Silver.	In the form of sulphate, nitrate, or chloride, it enters into metallic lustres. The chloride of silver mixed with Cassian purple gives a violet tinge.									
Antimony.	Antimonic acid or its salt of potassium is employed for opaque glazes, the antimoniate of lead (Naples yellow) for the yellow ones.				Pistachio green.	Gives a gamut of yellows.			Yellow.	
Chromium.	The oxide gives pure greens with *non-ferruginous* pastes, and resists a high temperature; with alkaline glazes the tones are not harmonious. The chromates colour alkaline or lead glazes yellow and the mixture of the two orange red.			Bluish green.	Green in alkaline glazes.	Brownish black with excess of iron.		Green very little used.	With not too much chromate of calcium, roses and reds are obtained.	Gives pink with chalk in an oxidising atmosphere.
Cobalt.	The oxide has great colouring power, resists a high temperature, and gives always violet-blue which with addition of alumina becomes sky-blue.		Greenish blue.			Black or grey, brown with excess of iron.	Violet-blue.			Ultramarine blue.
Copper.	Cupric oxide, CuO, with an alkaline glaze in an oxidising atmosphere gives *turquoise blue*, which becomes greener with boracic glazes and less intense with lead glazes. In a reducing atmosphere it forms with alkaline glazes a purple-red, which with other glazes becomes orange-tinted or brown.	Pistachio green.	The copper gives back to the green the bluish tone of the chromium in the alkaline glazes.							

Iron.	Below 1000°, and in an oxidising atmosphere, ferric oxide gives a whole gamut from red to brown and violet. With alkaline glazes the colour is green or blue-green, with lead glazes it becomes yellow or brown. Yellow or red ochres are used.		Greenish black with excess of chromium.	Bluish black or grey with excess of cobalt.			Violet-black with excess of manganese.	Brown.		
Manganese.	The oxide gives a powerful reddish or bluish violet colouring with alkaline glazes, and violet-brown with lead glazes. It is much used for black in combination with other oxides.					Black, brown, or brown-yellow with excess of iron.				
Nickel.	The oxide is not used alone on account of its uncertain tones: yellowish green with alkaline glazes, earthy green with boracic glazes, and green-brown with lead glazes. Combined with iron for browns.					Bright brown.				
Tin.	The oxide is the base of the opaque enamels. The chloride enters into Cassian purple.									
Zinc.	The oxide alone gives opaque white; it is combined with other substances for many colours.		An alkaline and chalk chromate gives pink.							
Gold.	In the metallic form it is much used for simple gilding or gilding fired under-glaze. Its other principal use is its combination with chloride of tin to give Cassian purple.								In the form of stannous and stannic chloride it gives with chloride of gold Cassian purple.	
Uranium.	The oxide is pale yellow in the alkaline glazes, dark and orange yellow in lead glazes. In a reducing atmosphere it gives blacks.						Violet black with excess of manganese.			

which is poured into water to disaggregate it. As vitrification requires more fuel than fritting, it is only used when indispensable for making glazes homogeneous; fritting, on the other hand, is preferable when the glazes contain chlorides or sulphides, on account of the substances which are formed, and which, in the fusion, would remain in the mass and produce explosions on contact with the water.

Frits are crushed either in the dry or the moist state according to the mode in which they are to be used.

As glazes are generally laid on in a state of paste, the mixture of their ingredients is generally effected in the presence of water.

The glazes thus obtained are colourless; but in order to colour them, it will be sufficient to incorporate in them a metallic oxide, but most frequently it is done by melting the whole together, then crushing and bringing it to the state required for the application. Coloured glazes are called enamels.

The opaque enamels are of stanniferous base, and their principal constituent is *calcine*, a mixture of oxides of tin and lead in variable proportions obtained by calcining a mixture of lead (100 parts) and tin (15 to 35 parts) in a reverberatory furnace to a dull red heat. An average quantity of 120 kilog. of metals is treated, and yields 132 kilog. of calcine. This is then mixed with its own weight of Nevers sand, 2 per cent. of soda, 8 per cent. of salt, and 2 per cent. of minium, and the whole is melted. A high degree of heat is necessary to succeed in rendering the mass quite liquid, which is an indispensable condition. It is cooled, pounded, and crushed in presence of water to a state of fine division. Thus we get white enamel.

In order to obtain the other opaque enamels, oxides in a state of fine powder are added to the enamel. These are incorporated with it before it is fused, and consequently we get a more intimate mixture and can observe the colour better.

The fusibility of enamels varies with the nature of the pottery and the degree of firing to which it is subjected. The lower the temperature of firing is, the more varied are the enamels, and as it rises this variation diminishes, for it is not all colours which can

resist a great heat, and only a small number of them remain fixed under the high temperatures of porcelain firing.

HARMONY OF GLAZES AND PASTES. — The preparation of glazes and their composition would be relatively easy to carry out if it were not necessary to harmonise their physical properties, fusibility and dilatation, with those of the pastes which they have to cover. In fact, if this harmony does not exist, the glaze crazes or peels off.

The crazing or chipping is due to an excessive contraction of the .glaze, causing penetration of the liquids which produce fissures when cooling takes place. If, on the other hand, it is the paste which contracts too much, there is peeling, that is to say, that in cooling the glaze becomes detached from the clay.

The dilatation of glazes and pastes is intimately connected with their composition; hence the first care of the ceramist is to become acquainted with the properties of the substances contained in the glazes and pastes. As regards the former, he must note that *alkaline silicates* are very fusible and contract much; that the *silicates of lead*, which are also very fusible, contract less; and that the other *metallic silicates*, that of copper excepted, undergo less contraction than alkaline silicates. The same may be said of the borates. The degree of fusibility of the silicates comes in the following order: lead, copper, manganese, cobalt, iron, uranium, chromium, nickel. If several enamels are applied to the same piece, they must melt at the same temperature, and it will be therefore necessary to diminish the fusibility of some and increase that of others by suitable additions of fluxes on set substances.

As for pastes, it must be observed that silica is very expansive, and that this property increases with the fineness of the grain, but diminishes when the grain is coarser or clay is added. Carbonate of lime and the alkaline sulphates alter the dilatation of pastes; they are therefore used to place them in harmony with the glaze.

The firing of the pieces to which glaze is applied may also lead to accidents, especially in the case of those which require a high temperature.

According to Deck, the following is the course to take in order to produce harmony between a paste and its glaze, the composition of both being known.

Composition of the Glaze.	To avoid chipping or peeling, we must :		Remarks.
Minium.			It must not be forgotten that what prevents chipping tends to produce peeling, and *vice versâ*.
Sand	Increase or	Diminish or	
Potash and soda	Diminish.	Increase.	
Composition of the Paste.			
Rich white clay	Diminish.	Increase.	
Chalk . . .	Increase if the paste is to be more calcareous.	Diminish.	
Flint	Increase or crush finer.	Diminish or do not crush so fine.	
Frit	Increase if the paste is to be more alkaline.	Diminish.	
Firing.			
Ordinary pottery	Biscuit not much fired.	Biscuit too much fired.	Regular firing necessary.
Silicious pottery		Biscuit not much fired.	A too strong firing causes fissures.

The question becomes still more complicated when coloured glazes are used, for it may happen that the most convenient composition for obtaining the desired colours is easily warped or is exposed to peeling. Only numerous experiments can help us to overcome these difficulties as they arise, and the scientific researches carried out with regard to this question have not hitherto been of much help to ceramists.

Special Processes of Decoration.

Application of the Glazes.—They are applied in various ways : the pottery may be sprinkled with them, it may be immersed in a pulp formed of the glaze, or the latter may be applied by volatilisation.

In the first case, the pottery while still fresh may be coated with the glaze in a powdered state, which is generally an oxide of lead or of *alquifoux*. Silica and alumina are provided by the piece to be glazed. This process, which is the simplest and commonest, is only used for common pottery.

Immersion consists of the pottery in a dry state, either warmed or baked, being dipped into a pulp of the glaze neither too thick nor too clear to be absorbed by the paste. The composition should be such that the glaze will not become detached after mixture; hence it must have a certain plasticity.

Glazing by *volatilisation* is effected by throwing saline or metallic substances into an active kiln; these will attack the surface of the pottery and will form on it a thin layer of a transparent glass which constitutes the glaze. In other cases, instead of throwing the vitrifiable substances on the pottery when in an incandescent state, the interior of the cazettes containing the pieces is coated with the glazing material. When the heat becomes fairly strong, these substances (alkaline carbonates or borates, oxides of lead) become volatilised and act on the surface of the pieces.

Instead of plunging the piece into the glaze, the latter may be poured upon it, and this is to be preferred in the case of pastes which are not very porous and which would not, by immersion, absorb a sufficient layer of glaze. This process is called *irrigation*.

Sometimes the pottery is sprinkled with a brush dipped in the glaze; this is the *sprinkling* process, and used for coating pieces on certain parts in order to obtain special effects.

If we desire to cover a piece entirely by this process, we must use *insufflation* or *pulverisation*, the principle of which is well known.

A tube with a small orifice is dipped into the glaze pulp; another tube is fixed at right angles to the first, and introduces the air under pressure; the current of air causes an aspiration which draws the liquid into the other tube. For small objects an india-rubber pear will be enough, but for large surfaces we must have bellows which will transmit the air at a pressure of $\frac{1}{3}$ to $\frac{1}{4}$ of an atmosphere.

Decoration with Enamels.—Opaque Enamels.—These are almost always stanniferous, the white enamel being the base of them. This enamel is prepared by melting together: 44 parts of calcine (oxide of tin and lead), 44 parts of sand, 2 parts of

Alicante soda (soda partially carbonated), 8 parts sea-salt, and 2 parts of minium (Deck). The mixture is roughly pounded, then finely crushed in presence of water until it has the required consistency. The coloured opaque enamels are obtained by adding different metallic oxides to the preceding mixture.

Formula according to Brongniart.		White Enamel.	Enamel obtained.
Naples yellow or oxide of antimony	9 p.	91 p.	Yellow.
Oxide of cobalt or azure . .	5 p.	95 p.	Blue.
Battitures of copper . . .	5 p.	95 p.	Pure green.
,, ,, . . .	4 p.	94 p.	Yellow green.
Naples yellow	2 p.		
Peroxide of manganese . . .	4 p.	96 p.	Violet.

Several methods are employed for decorating pottery with opaque enamels:

The method of *decoration "au grand feu" on unfired enamel* consists of coating the piece by *immersion* or *irrigation* with white enamel, which is allowed to dry, and then of placing on the friable raw enamel other opaque or coloured enamels by means of a brush or by any other quick process, such as spraying. The whole is then fixed by baking.

Instead of working with raw enamel, we may decorate on fired enamel. In this case the firing which fixes the decoration is done at a somewhat low temperature; this allows of the use of a very rich gamut of colours, which should be easily vitrifiable.

When a clay which is naturally white or whitened by dip is decorated, the stanniferous enamels may be replaced by transparent enamels, whose brighter colourings give different effects from those obtained with the opaque enamels. The presence in the paste of a sufficient quantity of limestone allows of either transparent or opaque enamels being used, the latter being especially reserved for light tints and white. The effects may be still more varied by giving dull tones to the enamels; for this purpose they are simply hardened, that is to say, they are rendered less fusible by the addition, for instance, of silica or alumina.

The alkaline transparent enamels are applied to all faïence pastes. From the point of view of architectural decoration, they conduce to powerful effects and have the very interesting

property of remaining as bright in artificial as in solar light, while under similar conditions lead enamels become dull. But the difficulty and delicacy of the preparation of alkaline enamels limit their use. Deck, the first ceramist who used them, gives the following fundamental formulæ which, by varying the quantity of flux, may serve to make an infinite number of intermediate tints :—

TRANSPARENT ALKALINE ENAMELS

	Lapis-lazuli Blue.	Yellow-brown.	Sea-green Jade.	Garnet.	Ivory.	Yellow Ochre.	Opaque Yellow.	Turquoise.	Green.	Camellia Green.	Olive Green.	Dark Violet.	Green.	Remarks.
Flux (1)	95	44	52	82	52	45	47	93	35	45	89	92	30	(1) Melted together:
Antimony (oxide of)	...	...	...	2	...	...	4	...	...	...	...	...	...	Minium . 30 or 35 parts.
Cobalt ,,	0.7	...	...	...	...	...	...	...	...	...	...	0.6	...	Sand . 50 or 45 ,, Pot. carb. 12 or 12 ,,
Copper ,,	4.3	...	0.7	...	...	...	...	7	4	5	3.4	...	4	Sod. carb. 8 or 8 ,,
Iron ,,	...	8	1.8	...	3	10	4	...	...	5	6.1	...	...	
Manganese ,,	...	13	...	6	...	...	...	...	...	...	2.5	7	..	
Nickel ,,	...	...	..	5	...	...	...	...	...	...	...	...	...	
Lead (plumbate of)	...	25	...	25	25	25	25	...	55	25	...	...	55	Minium.
Potash (nitrate)	..	...	..	5	...	...	...	...	5	...	...	...	10	
,, (carbonate)	...	...	...	...	...	...	..	...	...	...	...	...	...	
Sand	...	20	...	20	20	20	20	...	...	20	...	...	..	
Sodium (borate)	...	...	...	...	...	...	..	...	5	...	...	...	5	Melted borax.
,, (oxide)	...	..	...	5	...	...	...	...	...	...	...	...	...	Soda.

The different mixtures are melted, then crushed and applied to the biscuit or fired faïence. Application over engobe is not necessary, but this method gives more delicacy to the products.

In order to deposit a uniform layer of enamel we immerse in the coloured paste, which has been thickened by gum or some other viscous substance. If we wish to make *reserves*, we lay with a brush on the biscuit, in the places to be reserved, a coating composed of chalk and gum or essence, and immerse in the glaze. A moderate heat then causes the colour to adhere and the portions deposited on the reserves to fall off, thus leaving them bare. If coloured reserves are desired, the colour or colours which are different from those of the background are diluted with oil and applied with a brush to the required parts. Then, when immersion takes place, the colour of the background, which is diluted with water, does not adhere to the oil decoration.

Special effects are obtained by giving different thicknesses to the enamels, either by *running* (p. 402), or by filling the hollows in the terra-cotta with enamel. In this case hollow impressions are made either by moulding or engraving on the pieces when fresh. If the design requires several pieces, as in the case of decorative panels, it is made up of quarries of this kind.

The effects obtained differ according as the transparent coloured enamels are applied to the paste when unfired, fired, or warmed (biscuit). When they are placed close together, they have a tendency to run together at the moment of fusion. This inconvenience may be avoided by tracing the outline of the design with a black and less fusible glaze of sufficient relief. The coloured enamels are applied within these outlines. This process, wrongly called *cloisonné*, was used by Deck in 1874, and has since spread with astonishing rapidity in France and abroad.

Decoration with Colours.—In the case of enamels, the colour is incorporated in the glaze, which if transparent forms a coloured glass; it is otherwise in decoration with colours. Colour and glaze are applied separately; sometimes the latter covers the former, and this is *under-glaze decoration*; sometimes it is the reverse, and we have *over-glaze decoration.*

Under-glaze Decoration.—The colours, finely ground, are mixed with diluted gum or glycerine to render them more adhesive. They must resist the temperature of vitrification of the glaze, hence their composition depends upon the fusing point of the latter. They are often mixed with fluxes. They are applied to the warmed pottery by *immersion* for uniform tones, or with the *brush* when there is a design, or by *printing* when the same decoration has to be reproduced many times.

The brush-work is done with the colours mixed with gum or essence of turpentine; they are applied as in oil painting. When once dry, the pieces are heated before putting on the glaze in order to remove the essence.

Printing is done with copper plates having the design engraved on them by points; these are coated by means of a pad with the colour which has been prepared with boiled linseed oil and a little resin. The plates are heated to 30° or 40° C., to

facilitate the removal of the paper, to which the colour remains adherent. This paper is then applied to the pottery to be decorated and rubbed over with a pad, and is plunged into water so that the paper may be detached with a sponge. The pieces are dried and afterwards heated to 200° to 300° C., in order to remove the oil; they are allowed to cool, then covered with the glaze and fired.

The design obtained is monochrome, but other colours can be added with a brush, or more economically, if a large number of pieces are being treated, by printing.

For this purpose the design is divided among as many plates as there are colours, and the different colours are printed off separately upon the same paper, great care being taken to fit them together correctly. The design is afterwards transferred to the piece; this process is used in the decoration of facing quarries.

Chromolithographic printing, which is much employed in over-glaze decoration, presents certain technical difficulties when used under glaze. M. Boulenger, the eminent ceramist of Choisy-le-Roi, was the first in France to overcome them. Sarreguemines (Alsace) and Mettlach (Prussia), Minton and Hollins (England), also use sub-enamel decoration.

Machine-printing renders great services to the industry, but does not give such artistic effects as painting with a brush, which alone is capable of satisfying refined tastes.

Composition of the Colours.—This depends upon the nature of the paste to be decorated, both with respect to the colouring oxides used, and in the choice of the fluxes which are frequently added to them. As an example we shall mention the colours from which Deck has obtained such beautiful effects in his faïences of silicious paste, recalling, in their rich colouring, the celebrated Oriental faïences.

The colours having been finely crushed, are diluted by the muller, and applied with the brush.

Over-glaze Decoration.—This is performed with vitrifiable colours, that is to say, mixed with fluxes which generally vitrify at a low temperature. It is a very easy process, much used

Substances used.	Chinese White.	Persian White.	Light Blue.	Dark Blue.	Persian Blue.	Turquoise Blue	Dark Brown.	Red-brown.	Light Yellow.	Dark Yellow.	Black.	Rose (Pink).	Red.	Green.	Violet.	Remarks.
Flux (1)	(2)	(3)	..	85	(5)	80	(9)	(3)	(5)	(5)	(4)	(7)	(2)	10	55	(1) The flux is prepared with: Flint . . . . . 70 Carbonate of soda . . 10 ,, of potash . . 15 Minium 5
White clay	...	...	...	(4)	10	(4)	...	...	...	...	...	..	...	(4)	(4)	
Armenian bole	...	...	...	...	...	...	...	10	...	...	...	...	...	...	...	
Calcine	...	...	...	...	...	...	...	...	20	55	...	...	...	...	...	
Thiviers sandstone	...	...	...	...	...	...	...	...	...	...	...	...	10	...	...	Mix with care, melt, and grind.
Crushed porcelain	...	30	...	...	...	...	...	...	...	...	...	...	...	...	...	(2) Grind together: Persian white 20
Glaze of ,,	...	...	...	...	30	80	...	...	...	...	...	...	...	...	...	Stanniferous white enamel . 40
Nevers sand	...	20	...	...	...	...	...	...	...	15	...	...	...	...	...	(3) Grind together without melting.
Flint	...	...	...	...	...	...	...	...	...	...	30	20	...	30	...	
Aluminium (oxide)	...	...	...	...	...	...	...	...	...	5	6	2	...	5	...	Alumina.
Antimony ,,	...	...	...	...	...	...	...	...	4.5	73	22	..	...	20	...	
Ammonia (hydrochlor.)	...	...	...	...	...	...	...	...	0.8	...	...	...	...	...	...	Sal ammoniac.
Calcium (carbonate)	...	10	...	...	..	...	...	...	...	...	..	35	...	...	...	Chalk.
Cobalt (aluminate)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	(4) To be melted.
,, (nitrate)	...	...	(8)	...	...	...	...	...	...	...	...	...	...	...	...	(5) Mix and bake in a crucible under the kiln during a firing.
,, (oxide)	...	...	...	50	5	...	...	...	...	...	7	...	...	...	2	(6) Grind together, fire, wash, and crush.
Copper (oxide)	...	...	...	...	...	...	...	...	...	...	15	...	...	50	...	
Tin (oxide)	...	...	...	...	...	...	...	...	...	...	...	80	...	...	...	Stannic acid.
Iron (chromate)	...	...	...	...	...	...	40	...	...	...	20	...	...	30	...	(7) Precipitate with the ammonia a solution in water of: 12 k. alum and 9 k. of nitrate of cobalt, filter, dry, and calcine "au grand feu."
,, (oxide)	...	...	...	...	...	...	...	...	...	41	35	...	...	10	...	
,, (sulphate)	...	...	...	...	...	...	20	...	...	...	...	...	...	...	...	
Manganese (oxide)	...	...	...	...	...	...	15	...	...	...	40	...	...	...	55	
Lead (protoxide)	...	...	...	...	...	...	...	...	...	45	...	...	...	...	...	Litharge.
,, (plumbate)	...	...	...	35	...	10	...	2.5	6.5	50	44	...	2.5	40	30	Minium.
Potassium (bichromate)	..	...	...	...	...	...	...	...	...	...	...	4	...	...	...	(8) The mixture is heated for some hours at a bright red heat, then ground and washed in water acidulated with HCl.
,, (nitrate)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10	
Soda (borate)	...	...	...	...	...	...	...	...	...	...	...	4	...	...	...	Melted borax.
Zinc (oxide)	...	...	...	...	40	..	25	...	...	16	...	...	...	...	...	Flowers of zinc.

in pottery, and also by amateurs, but it gives rather dull effects, which are far from being equal to the decoration "*au grand feu.*"

The vitrifiable colours are obtained ready prepared in commerce. A large number of French (Poulenc frères, Lavoisier, etc.) and foreign firms supply them of excellent quality. It is only the great pottery factories which make them themselves.

The application is made with the brush, the colours being diluted with essence and oil. Sometimes the pottery is coated with resin dissolved in an essence or in oil, and is then powdered over with the dry colour.

In the trade *line-engraving* is used for monochrome designs, and *chromolithographic printing* for polychrome decoration.

The design, having been traced in outline with lithographic ink, is printed off in the ordinary way, on to as many stones as there are to be colours; the parts of each stone which are to be coloured are coated with a brush with lithographic ink; the remainder of the design is effaced, and the stones are placed in acidulated water to fix the ink and give it a slight relief.

The parts of the stone coated with ink are varnished by means of a wooden roller covered with leather, and a proof is taken off upon paper sized with gum or dextrine. The paper when taken off is turned over and sprinkled with a vitrifiable colour which sticks to the varnish; after drying the excess of colour is removed with a soft brush and the second colour is printed, great care being taken in fitting the sheet in its place. The process is thus continued until all the colours have been applied. To remove them to the piece of pottery, the prepared sheet of paper is covered with a varnish, and applied to it with a pad; when the varnish has adhered, the whole is plunged into water to remove the paper, is then dried, heated in the stove to remove the varnish, glazed, and fired.

This process, which gives good results with flowers and ornaments, is not so successful in reproducing animals or figures. We must then turn to photolithography, a process in which the sketch is replaced by a photograph; this is transformed into an

engraving, which can be reproduced by printing, for instance, by means of the bichromate gelatine.

The firing is carried out at a rather low temperature in special *muffled kilns* (p. 449).

Other Processes of Decoration.—These are exceedingly numerous, for ceramic decoration accommodates itself to every fancy, and the unforeseen results sometimes obtained add a charm to the decoration. The *crackling* effect is the utilisation of the fault called crazing. The glaze thus formed is covered with another, which penetrates into the crack and brings it out. *Mottlings* are produced by firing for a considerable time a fusible glaze which runs and makes unforeseen marbling effects. *Flashing* effects follow from the alternate use in firing of a reducing and oxidising atmosphere. By taking oxides which behave differently under the action of these, for instance those of copper, we get very diverse colourings, which, being unexpected, are very attractive.

The *metallic lustres* from which the East has obtained such wonderful effects, and which at the present day are treated in such a masterly manner by ceramists, are got by applying metallic salts crushed with vinegar or rich essence, with a brush, to the pieces fired under enamel.

Firing takes place in a muffled kiln at a low temperature, that of early red, in a smoked atmosphere (reducing). The pieces are put in open-work saggers, and come out with a layer of black on them; this is removed, and under it appears the brilliant decoration.

Deck gives the following ingredients :—

Gilded lustre.

Sulphide of copper	10	Sulphide of copper	5
,, iron	5	Nitrate of silver	2
,, silver	1	Colcothar	1
Yellow and red ochre	12	Armenian bole	4

Red lustre.

Sulphide of copper	2	Oxide of copper	8
Protoxide of tin	2	,, iron	5
Smoke black	1	Colcothar	6
Red and yellow ochre	4	Armenian bole	6

Gold and platinum are also used, and on account of their inability to be oxidised, they may be fired in an oxidising atmosphere.

Gold has also been applied *under glaze.* The effect produced is very powerful, and much more sparkling than gilding over enamel; the difference is of the same kind as that observed between transparent coloured enamels and under-glaze painting. This decoration is obtained by lightly enamelling the pieces and sprinkling them with grains of sand, then firing; gold-leaf, cut to shape, is applied with a stiff brush to the piece, which has been smeared over the required part, with a decoction of quince-pips. The glaze is then laid on, and the piece is fired at a temperature lower than that of the fusion point of gold (1045° C.). This kind of decoration requires great care, great taste, and very pure materials. It has been skilfully used by Th. Deck, who has been able to obtain remarkable effects from it.

CHAPTER II.

GLAZED AND ENAMELLED BRICKS AND TILES.

History.—In the ruins of Nineveh and Babylon, there have been found, side by side with ordinary fired or unfired bricks, others of which one extremity was glazed and even enamelled with different colours. The surface of these bricks is not smooth, it has designs in relief. It is probable that the bricks were collected together when in a fresh state, and that, after lines had been grooved on them to mark the outline of the design, and a sign to aid in fitting them together, each piece was coated with an enamel and carried to the kiln. The pieces were afterwards fitted together and fixed with water.

This Assyrian style of decoration has been observed in various forms throughout Asia Minor and even in ancient Persia, where, thanks to the remarkable discoveries made at Suse by M. and Mme. Dieulafoy, magnificent and irrefutable proofs of the use of enamelled bricks have been found.

These enterprising explorers have removed from the palaces of Artaxerxes Mnémon (4th century B.C.) and of the great Darius (6th century B.C.), the ruins of which lie one over the other, some important examples of enamelled decoration in a fine state of preservation, which can be admired to-day in the Louvre Museum in Paris.

One represents lions, another the facing of a staircase, and finally there is an admirable frieze on which twelve arches of the Royal Guard are represented in bas-relief. This work, whose harmonious tints are now mellowed by time, is treated with noble simplicity; there is something imposing in it which astonishes and compels admiration. Th. Deck has examined this frieze from the point of view of execution. The bricks,

which are 30 to 40 centimetres square and 9 centimetres thick, are made of sand mixed with a little clay and alkaline frits. The enamels are of tin base, and the colours are formed by the metallic oxides at present used by us. These enamels are more alkaline than ours, however, because of the large quantity of silica contained in the clay. The conclusion of the eminent ceramist is that this example of manufacture is an extremely remarkable one, and quite worthy of serving as a model for architectural ceramic decoration.

Muller has reproduced these friezes on enamelled stoneware, and we have been able to examine this fine example of pottery-work at the Chicago Exhibition and at the annual Paris Salons.

The Greeks and Romans were certainly acquainted with the art of enamelling pottery, but for some unknown reason they rarely used colours, a strange circumstance with a people usually so fond of them. Even under Hadrian (2nd century), when the Egyptian style was very fashionable, the Romans did not carry their imitations so far as to use the enamelled facings of which they could have found such fine examples in Asia Minor.

This was evidently the cause which retarded the appearance of faïence in Europe. It was at Troyes, in 1220, that plumbiferous glaze first appeared on terra-cotta roof ornaments. It was frequently used for varnishing facing bricks and the *pureau* (part uncovered) of tiles intended for roofing public buildings. To make those mosaics in colours, which adorn the roofs of many cathedrals of that period, especially that of Troyes, the tiles were coated with a coloured dip, red, black, yellow, or green, and the whole was covered with a lead glaze.

The popularity of these products lasted till the 16th century, then declined. Bricks which become varnished black in wood-firing were, however, always used in architectural decoration.

The enamelling of bricks suffered the same fate as their glazing, and it was only in the 19th century that it was revived, not only for decoration, but also for the hygiene of dwelling-houses. England, which is always at the head of any movement in pottery, anticipated us in the use of enamelled brick for the

inner courts of houses, for servants' staircases, privies, etc. The imperviousness of these products gives them precious qualities from the point of view of hygiene and cleanliness.

The movement is much slower in France; people fear that enamelled products will not wear, and their high price is objected to. When we look at some of our façades crowded with costly sculptures, we ask ourselves whether a little economy could not be realised here, and whether, in less beautiful but equally indispensable parts of the houses, materials could not be used which present incontestable advantages over painting and are less costly to maintain.

Varnishing. — Varnishes are *colourless transparent glazes*, generally plumbiferous, which are applied to bricks and tiles to make them impervious and also to decorate them, either simply by bringing out their colour or by modifying it by placing the varnish over a dip.

Simple varnishing is done with alquifoux or minium, mixed or not with silica; in the first case the varnish borrows the silica it requires from the paste of the pottery. Here are two old formulæ:—

Alquifoux	80	Minium	67
White sand	12	White sand	24
White clay	8	White clay	9

The varnish is laid on the products when unfired.

The process, which consists of sprinkling the products when still fresh with powdered fluxes, is not to be recommended on account of the dust which it causes and which is doubly dangerous both as being inert matter and as poison. It is advisable to use the immersion process. Generally only one side of the brick is glazed (end or side); sometimes, for angles in building, both.

The other non-plumbiferous glazes are scarcely ever used on account of their higher price; a saturated solution of sea-salt is, however, recommended, in which the products are dipped when quite dry; they are then again dried and fired.

This silico-alkaline glaze requires pottery rich in silica to obtain good adhesion.

The preceding glazes allow the colour of the products to be seen. If it is desired to hide this colour, the glaze must be placed over a dip; this renders the manufacture a more delicate operation, as has been explained in the general remarks on dips, for we must obtain a similar dilatation of the paste, dip, and glaze, if we are to get perfect products.

The glaze, when placed over a dip, is much more brilliant than when placed direct upon the paste, but it is more likely to crack. In fact, glazed bricks and tiles are rarely free from this fault. Manufacturers do not take the trouble, as they ought, to accommodate the glaze to the paste of which the pieces are made. It is true that, in the case of tiles, the disadvantages which would result from the water staying in the cracks of the glaze are avoided by giving a great slope to the roofs; this adds to the architectural effect, but necessitates a larger quantity of products which are in themselves already dear; therefore the consumption of tiles which are glazed over dips is necessarily limited.

Enamelling.—The enamelling of bricks and tiles, like glazing, is intended to render them impervious and to produce a decorative effect by means of colouring. Enamelled bricks are really faïences, and as in the case of these latter, the enamel and the paste must be in harmony to avoid cracking; but besides this, the adhesion between the two bodies must be such that the bricks may be able to resist frost, damp, the different degrees of dilatation of summer and winter, etc.—in a word, all variations of environment.

It will be understood that these conditions are not satisfied in common pottery, and no means have yet been found of applying to ordinary bricks an enamel which fulfils the conditions of solidity mentioned above.

It was in consequence of accidents which have happened to enamelled bricks used in the construction of subterranean arched passages, that attention was called to their powers of resistance to inclemencies of the weather.

For instance, under certain conditions of damp this resistance is not so great as that of ordinary bricks, and in these

special applications it will be well to make arrangements for putting enamelled bricks in the best possible state to resist inclemencies.

In order to avoid such inconveniences, manufacturers have still further improved their products; for instance, Muller applies enamel to bricks made of stoneware firing clay.

Loebnitz uses faïence paste moulded by hand. The enamel adheres firmly to such paste, becomes a part of the piece, and thus satisfies the required conditions of solidity.

Engineers have gone a step farther, and have had recourse to porcelain bricks. An important use of these products was made in constructing the tunnels of the extension of the Sceaux line to Luxembourg. Time will show the value of these impervious products under such conditions; in any case, they cause a very heavy expense.

Without going as far as this, it is evident that the examples left behind them by the ancients prove that enamelled products successfully resist the lapse of time when they are well made and used with certain precautions.

The moulding of bricks which are to be enamelled is similar to that of ordinary bricks; nevertheless hand-moulding seems to be preferable, perhaps on account of the greater porosity of the resulting products.

The enamel holds less well to machine-expressed bricks, or even to those simply stamped—stoneware bricks excepted.

Transparent enamels can only be used directly in certain cases, for, bricks being always coloured, a contrast of tints is produced. With orange or red pastes, we can obtain brown with an enamel containing about 5 per cent. of oxide of manganese, and black if oxides of iron and cobalt are also added; all other colours require a dip.

Yellowish pastes will, with manganese and iron enamels, give red or brown colourings, with those of copper green, and with those of cobalt blue. But white and light colourings can only be obtained with dips or opaque enamels, unless we work upon white pastes like those of fine stoneware or felspar faïence, which form exceptions.

The composition of some enamels is given below—

	Blue.		Brown.		Yellow.		Black.		Green.	
Alquifoux	81	...	78	60	78	63	77	...	76	63
Minium	...	66	3	...	3	...	...	58	...	...
White sand	12	24	10	...	11	23	8	...	12	23
White clay	6	9	6	...	8	9	6	...	6	9
Vegetable mould	...	...	...	33	...	...	...	32	...	...
Sulphate of iron	...	...	...	5	...	5	...	5	...	...
„ copper	...	...	...	...	...	...	3	3	6	5
Oxide of manganese	...	...	3	2	...	...	3	2	...	...
„ iron	...	...	...	...	...	...	3	...	...	...
„ cobalt	0.3	0.3	...	...	...	...	...	0.04	...	...

Applications.

Ordinary Enamelled Bricks.—These are of decorative and hygienic interest in the facing of walls. For decorative purposes white and coloured enamels are used. As surfaces of a uniform white are disagreeable and cold to the eye, the enamel is marbled with a greenish tint, which gives a more attractive and softer general appearance. Ornamentation of this kind may be seen in Paris at the Café Riche (executed by Lœbnitz), and on a larger scale at the Hotel des Téléphones (Perrusson). The architect of this latter building does not seem to have obtained the best possible artistic effect which might have been expected from the use of such materials.

The polychrome style with bricks enamelled in colour offers great resources through the variety of designs which may be executed in it. The patterns composed of ordinary red and white bricks are already very numerous, and the number may be increased indefinitely by the use of enamels of varied tints.

But to arrive at a harmonious effect, without any discordant note, a great knowledge of colour and skill in composition are required, qualities not found in every architect.

Figs. 705–710 represent some simple patterns obtained with bricks enamelled in colour.

As regards hygiene, the white enamelled brick presents the great advantage of being impervious and easily cleaned. By the

reflection of light on its white surface it helps to illuminate dark places such as inner yards, arched passages, etc.

Bricks of Glazed Stoneware.—The clay used for these bricks is the same as that used for making stoneware pipes. The glaze is obtained with sea-salt, as will be explained in speaking of stoneware pipes. These bricks are made solid or hollow, and are of the usual dimensions and shape. Special bricks for garden borders (Figs. 713, 714) are also manufactured. Others are


Fig. 705.

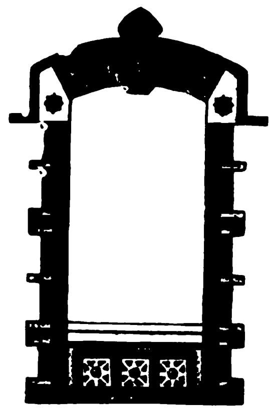


Fig. 706.


Fig. 707.


Fig. 708.


Fig. 709.


Fig. 710.

Figs. 705 to 710.—Patterns in Enamelled Bricks (Perrusson).

hollow and are used for copings (Figs. 711, 712), either single or in combination, according to the breadth of the walls to be covered.

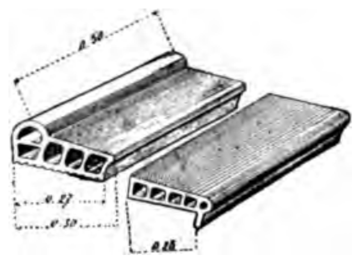
They are laid on a bed of mortar with horizontal levelling, but without filling.

Bricks of Enamelled Stoneware.—Besides the solid bricks of enamelled stoneware, which may advantageously take the place of ordinary bricks, special hollow bricks, enamelled on one or

both sides, are also made for the economical facing of walls and the construction of partitions.

Bricks enamelled on one face have various dimensions (Figs

Fig. 713.



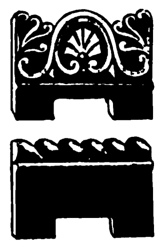


Fig. 711. Fig. 712. Fig. 714.

Figs. 711 to 714.—Bricks of Glazed Stoneware (Jacob et Cie.).

HOLLOW BRICKS AND ENAMELLED "BARDEAUX."

Fig. 715. Fig. 716. Fig. 717. Fig. 718. Fig. 719. Fig. 720.

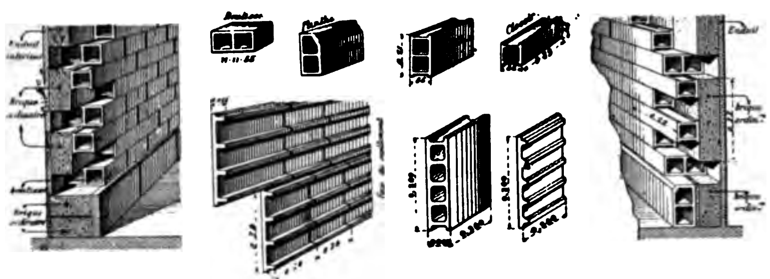


Fig. 721. Fig. 722. Fig. 723.

Fig. 727.

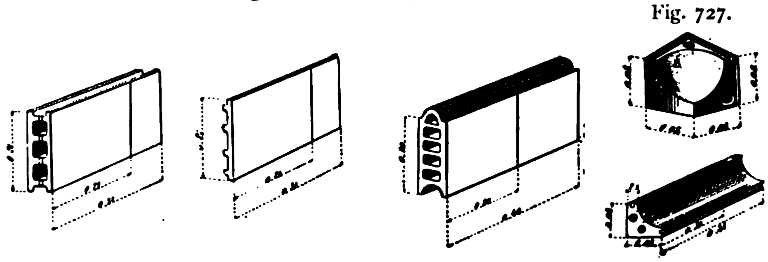


Fig. 724. Fig. 725. Fig. 726. Fig. 728.

Figs. 715 to 723.—(Muller.) Figs. 724 to 728.—(Jacob et Cie.)

716, 718, 719), and Figs. 715 and 712 show the manner in which they are used.

For the above-mentioned bricks may be substituted plates

(Figs. 723, 725), which are obtained by vertically cutting "bardeaux," large hollow bricks enamelled on both sides (Figs. 722, 724). The ribs formed by cutting are used for fixing the plates to the coating of the wall (Fig. 721).

"Bardeaux" enamelled on both faces (Fig. 726) are used for constructing partitions having the thickness of a "bardeau" and requiring to be faced on both sides.

For the bottom of the walls, bricks in the shape of plinths (Fig. 717) or grooves (Figs. 727, 728) are used in order to avoid any angle in which dust may accumulate; this is of great importance in certain cases—in hospitals, for instance.

Enamelled Tiles. — These are used in the same way as ordinary tiles, but the roofs must be given a great slope, for reasons indicated above. We may recall the immense mosaic of bright and harmonious tints, due to the architects Formigé and Bouvard, which covered the domes of the Palaces des Beaux-Art and des Arts Décoratifs at the International Exhibition of 1889.

More than two hundred thousand enamelled tiles of various shapes—six hundred and twenty different types were necessary—were made for this work by Emile Muller, of Ivry.

CHAPTER III.

Decorated Quarries.

According to the uses for which they are intended we must distinguish between—

I. Paving quarries, either plain or decorated with dips, without glaze.
II. Facing quarries, plain or decorated, glazed.
III. Stove quarries, plain or decorated, glazed.

Each kind requires special qualities, according to its destination; a facing quarry cannot be used for paving, and, even if certain stove quarries may under certain circumstances be applied to facings, the contrary, as we shall see, is certainly not true.

I. PAVING QUARRIES.

With respect to their ingredients, these quarries are divided into—

1. Quarries of ordinary clay decorated with coloured dips.
2. Stoneware quarries of various kinds.

1. *Quarries Decorated with Dips.*

These must, without doubt, have been used, like enamelled bricks, by the earliest peoples, but their history is not known; we know well, however, that of the incrusted tiles which were made with such brilliant success during our Middle Ages. In the 8th century we find pavements adorned with designs roughly executed in relief, unglazed, but laid down with glazed quarries. According to Amé, the oldest quarry known dates from 853; it bears an inscription under the dark green and very thick glaze. From the 9th to the 11th century, a period of ruin and

struggle, scarcely any progress is to be noted in this branch of pottery. In the 11th century, monochrome unglazed pavements are found with incrusted designs; this simplicity was required in the Cisterian churches, and is in contrast with the rich decoration of the Clunician churches and abbeys. The death of Saint Bernard removed the severe rules which he had enacted, and it is actually to the Cisterian abbeys that we owe those important improvements in terra-cotta pavements at the end of the 12th century, due to the use of inlaid clays of various colours.

The pavements at the beginning of the 12th century are formed of small quarries of a single colour but of various shapes, often inlaid with a small piece of terra-cotta of another colour. The combination of all these bold-coloured squares, red, yellow, green, and black, form a kind of mosaic and give a fine effect, as may be seen by the pavements of that period still in existence at Saint-Denis (Seine), and Sainte-Colombe-lez-Sens (Yonne). The dominant colours of these pavements are black and green.

At the end of the 12th century inlaid squares appear, with or without glaze, in which black predominates. One of the most beautiful pavements of that period is that of Saint-Pierre-sur-Dives (Calvados). The 13th century made great use of these quarries in different colours; red predominates, yellow-green tends to disappear, black and brown are used to enclose divisions, but we observe in the manufacture less care and choice than in the 12th century; nevertheless some of these pavements are of great beauty.

In the 14th century the designs of incrusted quarries become more confused and more scanty; a profusion of initials, arms, and inscriptions are introduced into them; green and light blue appear among the colours; black becomes rare. Ornamented pavements of the 14th and 15th centuries abound in Champagne and Burgundy.

In the 16th century we see, side by side with incrusted squares, faïence quarries in which white, yellow, blue, and green predominate, and which form the marvellous pavements of Ecouen, Blois, Langres, etc. The bright colours of these quarries

were soon preferred to the naturally duller tints of clay squares, and for more than a century, faïence pavements were in fashion. Then came the decadence, and in the 17th century, paving with incrusted quarries fell into complete oblivion.

It was the Englishman Wright of Staffordshire who revived the old processes, and it was Herbert Minton, assignee of Wright's patent, who succeeded in overcoming all difficulties and in manufacturing products superior to those of the Middle Ages in quality and decoration. The industry passed from England into France, where to-day there are important factories which make exclusively that type of quarry.

Manufacture.—After the clays have been crushed, washed, decanted, and filtered, they are brought into a state fitting them for moulding by the following method.

The plaster relief of the pattern required is placed at the bottom of a plaster mould, and a first layer of clay of the first quality is applied with the hand to this relief, then another layer of less good clay, then another of inferior quality, and so on, until the proper thickness of the quarry is reached.

The whole is then placed under a quarry-press and strongly compressed, the relief at the bottom of the mould being printed in hollow on the clay; the slab is then removed from the mould and taken to the drying-room. When the paste is sufficiently hardened, the various naturally or artificially coloured dips are poured into the hollows in a state of paste, and the slab is left again to dry. After a sufficient desiccation, the surface of the quarry is freed from irregularities, it is polished, and drying is allowed to continue slowly, being completed in twelve to fifteen days. Firing may be effected in any suitable kiln.

One of the difficulties of this method of manufacture is the avoidance of the unequal contraction of the different layers of clay. The pastes used should therefore be prepared and tested with this view.

As the use of clays of different qualities is only intended to reduce the amount of fine clay, there is no reason why a quarry should not be made of the same clay throughout its thickness; moreover, instead of executing the design by means of dips

applied to the surface, it may be made to traverse the whole mass of the quarry. The earliest pavements were formed in this way. The manufacture is more costly, but the products last longer. This question is now of secondary importance, for quarries of incrusted stoneware have entirely taken the place of those of ordinary clay.

2. *Stoneware Quarries.*

Stoneware is pottery made of hard paste, impervious and opaque, white or coloured, covered with a glaze or not. This definition, which at first sight seems clear, is difficult of application to intermediate products.

Imperviousness and hardness, distinguish stoneware from simple or made-up terra-cottas, but these are relative qualities; opacity distinguishes stoneware from porcelains, which are transparent, but where does transparency begin and opacity end?

Here again practice is better than rigorous classification. A man in the trade will not confuse a stoneware with a porcelain, and he will know with certainty whether a certain paste should be called stoneware or not.

However that may be, stoneware is obtained by the firing of clays, which contain naturally, or have added to them, substances called fluxes; the property of these is to effect in the mass a degree of softening sufficient to weld the molecules together and thus cause imperviousness, but not pronounced enough to cause loss of shape in the pieces. Clays which fire direct into stoneware are called natural stoneware clays.

Natural Stoneware Clays.—These contain a certain quantity of alkalies and lime, and sometimes of oxide of iron, which act the part of fluxes. The proportion of them should be such that the paste is neither too fusible nor too infusible; the composition of these clays must then vary between narrow limits which average—

Silica	68 to 75 per cent.
Alumina	20 to 25 ,,
Lime and magnesium	10 to 20 ,,
Alkalies	3 to 5 ,,
Oxide of iron	variable quantity.

Artificial Stoneware Clays.—These clays are prepared either by adding a refractory clay to a fusible one, or the reverse, *i.e.* by adding fluxes to a refractory clay.

In the first case, we must not think that all fusible clays will, when mixed with a refractory clay, give good stoneware. The properties of these clays must be such, that the softening takes place without injury to shape. In this respect, clays containing alkalies (2 per cent.) in the form of silicates or felspar, are preferable to those which are simply calcareous. As to the composition of the mixture, experience alone can guide us in each particular case.

The addition of fluxes to refractory clays also requires the aid of experience in estimating proportions. The substances used as fluxes are felspar and pegmatite for stoneware of good quality, and marls, or better still, blast-furnace slag (silicate of lime) for cheaper stonewares. The clays used are—according to the products required—kaolin and white or coloured refractory clays.

Colour of Stonewares.—This depends upon the composition of the paste, and varies from white to a more or less brownish yellow. White stonewares require pastes absolutely devoid of iron. A small quantity of this metal gives yellow, a larger quantity brown; and these colours pass into a more or less bluish grey if firing takes place in a reducing atmosphere. Real red tints are more difficult to obtain than with ordinary terra-cottas; a large proportion of oxide of iron is required, very little alkali, no lime, and a neutral final atmosphere, neither oxidising nor reducing.

According to the nature of their pastes, stoneware quarries, or those so called, are divided into—

A. Plain fired stoneware quarries	1. Of slag base. 2. Of fusible clay.
B. Plain or incrusted stoneware quarries	1. Of special clay firing to stoneware. 2. Of felspar base.

A. FIRED STONEWARE QUARRIES.

These quarries have some of the qualities of stoneware, such as hardness, but their paste is not absolutely impervious, and

even when entirely melted always remains slightly pervious. They are subdivided into—

1. **Quarries of Slag Base** (also called Pont-Sainte-Maxence, principal place of their manufacture).—They are made by mixing blast-furnace slag with special, and more or less refractory, rich clays. This substance, the residue of casting, is a double silicate of lime and alumina, with variable quantities of the oxides of iron and manganese; its great fusibility is due to the presence of lime. After having been crushed and reduced to powder, this slag is blended in a pug-mill with the clay; the mixture is then machine-expressed and cut to the required size. When the slabs thus formed have acquired a certain degree of consistency in the drying-rooms, they are stamped in the mechanical presses which have already been described, are again taken to the drying-sheds, and then fired in kilns.

The principal centres of this manufacture are: in France, in the l'Oise department, at Pont-Sainte-Maxence (Defrance et Cie.), at Auneuil (A. Boulenger), at Canteleu-Lille (De Smet et Cie.); in Belgium, at Jurbine and Tertre; in Alsace, at Sarreguemines; in Germany, at Ehrang-lez-Trier, Saint-Johann, etc.

PARTICULARS OF STONEWARE QUARRIES OR PAVING-SQUARES.

	Colour.	Shape.	Dimensions.		Weight.	Number to the Square Metre.	Price.	
							Per 1000.	Per Square Metre.
Boch frères	Yellow	Square	0.147	0.045	...	50	160	8
	,,	,,	0.170	0.030	...	33	240	8 to 9
Defrance	,,	,,	0.142	...	...	50	...	...
	,,	,,	0.160	...	...	38	...	...
Jacob	,,	,,	0.140	0.045	...	50	160	8
Muller	,,	,,	0.140	0.045	1.700	50	170	8
Perrusson fils and Desfontaines	,,	,,	0.170	0.040	1.650	33	...	7
	,,	,,	0.140	0.035	1.500	50	...	6.75
Simons	,,	,,	0.140	0.035	1.400	50	140	7
Smet (De)	,,	,,	0.140	0.033	1.400	50	120	6
	Black	,,	,,	,,	,,	,,	150	7.5
Société des produits céramiques (Boulogne-sur-Mer)	White	,,	0.140	0.030	1.200	50	...	6.75
	Black	,,	,,	,,	,,	,,	...	11.25
	White	,,	,,	0.035	1.400	50	...	7.00
	Black	,,	,,	,,	,,	,,	...	11.25
	White	,,	,,	0.040	1.600	50	...	7.25
	Black	,,	,,	,,	,,	,,	...	12.00

2. **Quarries of Melting Clay.**—These are made in various factories which are easily able to procure what are called melting clays—namely, clays which, used alone, begin to fuse under a strong firing, and thus bring the molecules closer together. The quarries made of these clays are of the same shapes as those of Pont-Sainte-Maxence, and they are called *artificial stoneware* quarries, ceramic quarries, etc.

Applications.

Stoneware quarries are used for paving sidewalks, yards, passages (Fig. 737), stables, factories, etc. They are generally 14 centimetres square and 4 centimetres thick; their colour is yellow, brown, or black. The surface of them is furrowed so as to prevent slipping and give a hold to horses' feet. The principal types (Figs. 729 to 736) are: the staircase quarry (Fig. 729), quarries striated in arabesques (Fig. 730), diagonally (Fig. 734), or in angles (Figs. 731, 732), the granulated quarry (Fig. 733), the "grand cross" quarry (Fig. 735).

The difference of colouring is taken advantage of to execute designs which break the monotony of the pavement (Fig. 737). The quarries are laid upon concrete or cement.

The quarries of clay which fire into stoneware are of the same shape as the preceding (Figs. 738 to 746), and their thickness varies from .035 to .45 metres; they are used for the same purposes.

Thus 739, 741, 742 are used for stables, yards, passages; 738 and 743 for side-walks; the plain square 738 is for factory hot-air chambers; and lastly, 744 is used as a kennel-stone.

According to their shapes, the quarries are cut in two medially or diagonally (Fig. 738) or diagonally only (Figs. 742, 743); the squares 741 can be divided into thirds or two-thirds, or into halves and quarters; and finally, the hexagonal quarry (Fig. 746) may be cut along AB or AC. Besides these, we have half-squares ready made (Fig. 740).

Fig. 729.

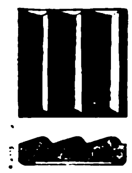


Fig. 730.

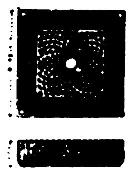


Fig. 731.

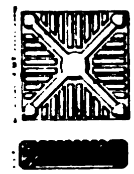


Fig. 732.

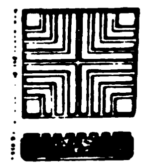


Fig. 733.

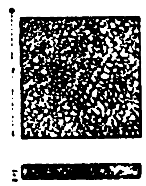


Fig. 734.

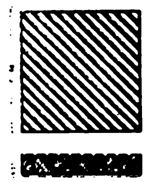


Fig. 735.

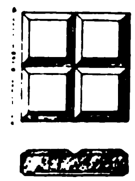


Fig. 736.

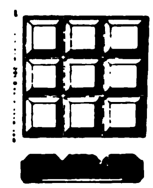
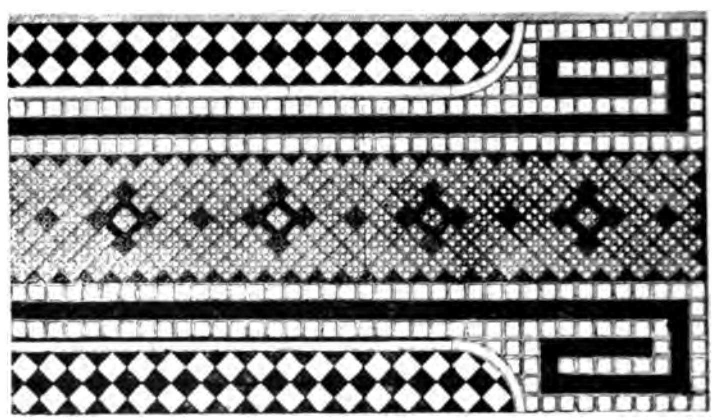


Fig. 737.



Figs. 729 to 737.—Various Quarries from Pont-Sainte-Maxence (Defrance et Cie.).

Fig. 738.

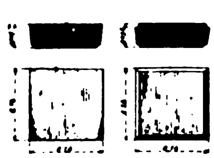


Fig. 739.

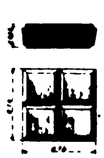


Fig. 740.

Fig. 741.

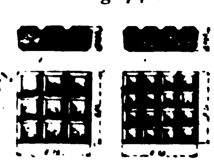


Fig. 742.

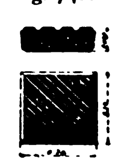


Fig. 743.

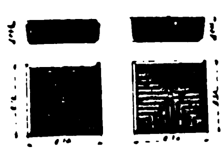


Fig. 744.

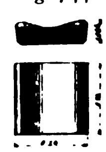


Fig. 745.

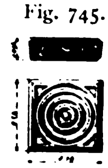
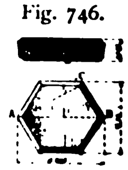


Fig. 746.



Figs. 738 to 746. Ceramic Paving Squares (Muller et Cie.).

B. STONEWARE PLAIN OR INCRUSTED QUARRIES.

1. **Of Special Clay Firing into Stoneware** (Stoke-on-Trent manufacture).—The Potteries district in Staffordshire is the principal and almost the sole centre in England of this manufacture. It was at Stoke-on-Trent, the chief town of the Potteries, that Minton began his attempts at the reproduction of mediæval encaustic tiles. Since that time, now many years ago, the primitive processes have been perfected, and a certain number of large houses successfully produce quarries of this type.

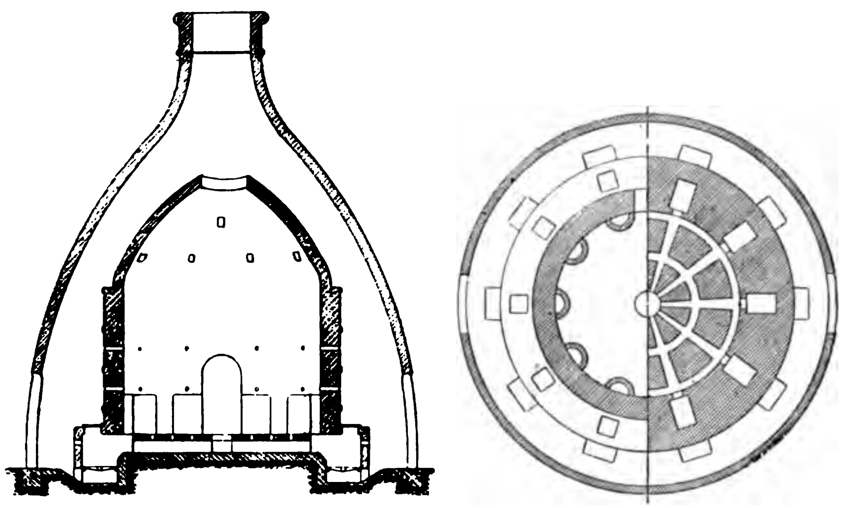


Fig. 747.—Direct-flame Kiln used in England.

In France, the manufacture of stoneware quarries inlaid with clays of different colours was introduced about the year 1855 by M. Boulenger the elder, of Auneuil, who remains still almost the only regular maker of that style of product.

Clays of special qualities are required for the manufacture of these quarries. The preliminary treatment consists of crushing in presence of water, and for that purpose the mills described on pp. 57 to 60 are used. Other mills, called block-mills (Fig. 748) are sometimes substitued; in these, the grindstones are replaced by large stones moved by the horizontal arms of a

vertical shaft. The bottom of the pan is paved with hard stones, and a ring prevents the blocks from rubbing against the sides of it. The advantage of these mills is that renewal of the grindstones is avoided. Alsing cylinders (Fig. 789) may also be used. When the clay is properly tempered, it is sent to the filter press, or, more simply, is left in the open air until it attains the proper degree of desiccation. Plain quarries are made from the clay when reduced to powder by some method. This powder is placed beside the press, which is generally a screw-press worked

Fig. 748.—Block-mill (Boulton).

by hand (Fig. 604). With one hand the workman fills the mould with the powder, which is moistened to the proper degree, and applies pressure with the other. This method of manufacture is a fairly quick one. After being removed from the mould the quarry is trimmed and polished, and then goes to the drying-room.

But when incrusted quarries are to be made, the moulding is carried out by the ancient process which we have described in the case of ordinary clay quarries decorated with dips. This

process requires a considerable amount of labour. The quarry is moulded with several layers of different pastes, the composition of which is such that their contraction is similar; the bottom layer lies upon a plaster mould, and by pressure the top of this mould is reproduced in hollow on the quarry. The latter is then taken from the mould and dried. When the paste is dry enough, the coloured dip, which is prepared separately in colour-mills (Figs. 701 to 704), is poured on to it, and it is again dried; then the second dip is laid on, the quarry is again dried, and so on. Finally, when all the dips have settled and are sufficiently hard, the excess is taken off and the pattern is disclosed; the quarry is then polished with a steel knife. This manufacture of polychrome incrusted quarries is less quick than that of the quarries of felspar base which we shall describe later.

After drying, the squares are fired in direct-flame kilns (Fig. 747), similar to those used for faïence; they are the kilns most generally employed in England. At Stoke, for instance, their tops are seen in all directions above the roofs of the factories. These kilns are not very economical, but the price of coal is not high enough to force manufacturers to improve upon their system of kilns. Firing takes place at a temperature high enough to transform the clay into stoneware, thanks to its natural composition.

Concurrently with this process we now use moulding with dry clay, which is more rapid. It will be described later on under the head of *Manufacture of quarries of felspar base.*

Applications.

The variety of designs, their composition, their colour, and the manner in which the quarries are combined, present an inexhaustible means of decoration from which everyone can draw according to his taste. Let us first give some specimens of French manufacture (Figs. 749 to 758). The groundwork of the pavement (Fig. 749) is composed of the quarries 755 and 757, and is framed with the square 756 and the border 754. The grouping of four quarries (Fig. 752) round 753 produces the

pattern 750. The quarry 752, used alone, gives a different effect when arranged as a border.

The English manufacture is of very varied styles, which change less often than in France, and, for that reason, are lower in price. This is due to a different method of work. An English house issues at great expense magnificent catalogues with which it will work for a number of years. All the types mentioned in the catalogues are made in large quantities; the patterns and colours are invariable, and therefore the cost is lower. In France, public taste demands frequent changes in the types made, and

Fig. 749.

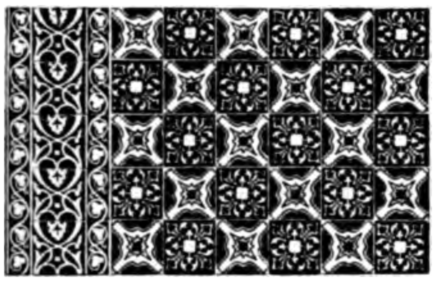


Fig. 750.

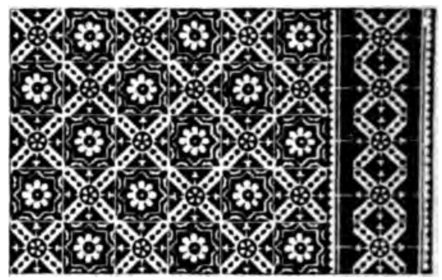


Fig. 751.

Fig. 752.

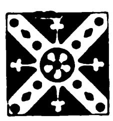


Fig. 753.

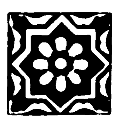


Fig. 754.

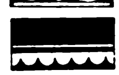


Fig. 758.

Fig. 755.

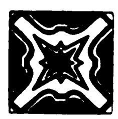


Fig. 756.

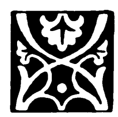
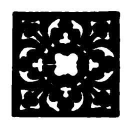


Fig. 757.



Figs. 749 to 758.—Incrusted Quarries from Auneuil (Boulenger).

this causes an increase in prices, as the quantity made of the same quarry does not sufficiently repay the always large outlay.

It would be impossible to mention all the important houses making incrusted quarries in England. Among the best known are: Messrs Carter & Co., Doulton & Co., Maw & Co., Minton, Hollins, & Co., Woolliscroft & Son, etc.; all of them produce pieces which are excellent both in quality and ornamentation.

Plain quarries are generally red, black, yellow, and grey; their shape is square (Figs. 766, 768), hexagonal (Fig. 759), or octagonal (Figs. 770, 771).

The combination of these quarries, together or with others, produces patterns of infinite variety (Figs. 763 to 771). Stone-

Fig. 759.

Fig. 760. Fig. 761.

Fig. 762.

Fig. 763.

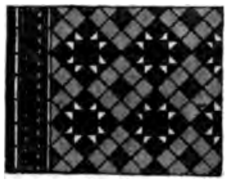


Fig. 764.

Fig. 765.

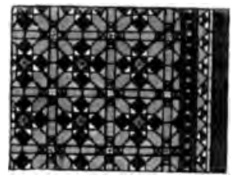


Fig. 766.

Fig. 767.

Fig. 768.

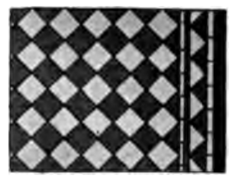


Fig. 769.

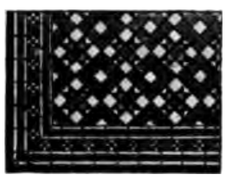


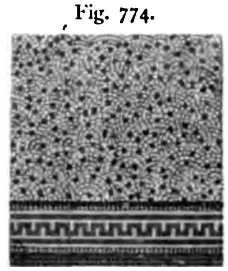
Fig. 770.

Fig. 771.

Fig. 772.

Fig. 773.

Fig. 774.



Figs. 759 to 774.—Plain and Incrusted Stoneware Quarries (Carter & Co.).

ware quarries are easily broken into small pieces, which are used for making coloured mosaics more varied and much more

durable than those of marble; this is of great importance in the paving of much-frequented places, such as public halls, cafés, hotels, etc.

These mosaics may be arranged in various ways. For instance, the little cubes may be placed in concentric circles (Figs. 773, 774); flowers (Fig. 778), geometrical patterns (Fig.

Fig. 775.

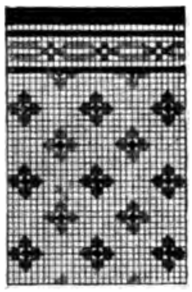


Fig. 776.

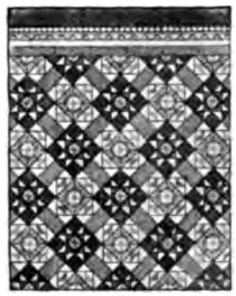


Fig. 777.

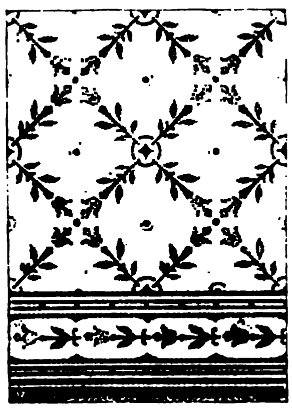


Fig. 778.

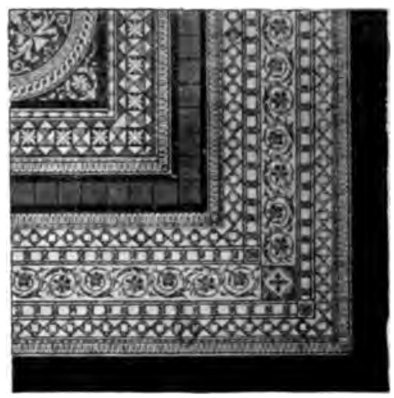


Fig. 779.

Figs. 775 to 779.—Incrusted Quarries (Encaustic and Mosaic Tiles of Minton, Hollins, & Co.).

786), or lastly letters (Figs. 780, 787), may be made with them.

In these mosaics the pieces are always irregular; regular mosaics (Fig. 775) are formed with little uniform cubes made by special machines.

Figs. 776, 777, 779, 781, 782, 783, 785 show the numerous combinations which can be effected with incrusted

Fig. 780.

Fig. 781.

Fig. 782.

Fig. 783.

Fig. 784.

Fig. 785.

Fig. 786.

Fig. 787.

Figs. 780 to 787.—Incrusted Quarries (Encaustic and Mosaic Tiles of Maw & Co.).

quarries. These illustrations lack the charm of colour which makes the pavements so attractive and agreeable to the eye. (See Plate I.)

The firm of Minton, Hollins, & Co. have executed some important pavements of incrusted quarries in England, especially that in the Palace of Westminster. The patterns of this pavement are remarkable and most effective in spite of the fact that only two colours, yellow and red, are used. Its great wearing qualities must also be noted: although laid down more than fifty years ago, it has borne the considerable traffic of the corridors and central hall without appreciable damage to the incrustations. The pavements of the South Kensington Museum, laid down by the same firm, are polychrome, and are in the form of mosaics of varied tints resembling the patterns shown in Figs. 775 and 776.

2. **Plain and Incrusted Quarries of Felspar Base.**—These quarries are made in France, Belgium, Germany, and Spain. They are made of a mixture of rich clays and felspar, to which, for the coloured portions, are added metallic oxides. The factories in the North of France obtain their primary materials from Luxembourg, the banks of the Rhine, Belgium, and England; those of the centre from a less distance, on account of the cost of transport—part of their primary materials comes from Diou in the Allier (H. Gay), hence there is a difference of appearance between their products and those of the North. The ingredients of the pastes must be more or less pure according to the type of quarry which is to be manufactured, and their quantities are a matter of experience only possessed by those who carry on this class of manufacture.

The best pastes are always the result of a mixture of several plastic clays thinned with a cement formed of powdered terra-cotta. White or only slightly coloured products require fairly pure pastes containing little or no oxide of iron.

The felspar acts as a flux in consequence of the alkalies contained in it (p. 5), and the quantity of it necessary in the paste depends upon the refractory qualities of the clay and upon the temperature at which firing is to take place.

We may take as an example of a paste giving a good fine white artificial stoneware—

Plastic clay	25 parts
Clay kaolin	25 „
Felspar	50 „

This stoneware bears a temperature of nearly 1500° C. The felspar may be replaced by the sands which are the residue of the washing of kaolins.

Colouring.—To produce the coloured patterns which adorn artificial stoneware quarries, metallic oxides are added to the mixture of pastes.

Black is obtained by the addition of oxides of iron and manganese (5 to 6 per cent. of each);

Blue with .5 to 5 per cent. according to the intensity required, of the oxide of cobalt;

Green is produced by the oxide of chromium (.5 to 1 per cent.), *bluish greens* by a mixture of oxides of cobalt and chromium;

Reds and *yellows* with yellow and red ochres (anhydrous and hydrated oxides of iron).

The intermediate tints are produced by mixing the above oxides in various proportions.

Manufacture.—This is performed with powdered dry clays. The primary substances are dried in large ovens heated to about 50° C. by one of the usual methods—hot air, steam, waste heat of the kilns, etc.

The clay may also be spread in a layer 6 or 8 inches thick upon stone or metal slabs heated underneath by waste heat. When large masses of material have to be dried, hot-air kilns are used. (See p. 55.)

Crushing of the Primary Materials. — Dry crushing is done with the crushing mills described under the head of the preparatory treatment of clays. In the case of white pastes, the use of iron must be avoided, and flint grindstones substituted. It is better to pulverise the felspar in presence of water in special machines like those shown in Figs. 748, 788, 789.

The Villeroy crusher (Fig. 788) consists of a ball of granite

weighing from 1000 to 2000 kilog. and rolling on a tray which is also of granite. Scrapers keep the sieve clean and bring the substances under the ball. This machine has a large output; with five horse-power, and the holes in the sieve being .004 m. (about ⅙th inch), it crushes 1500 kilog. of coarse felspar per hour.

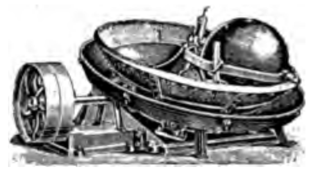


Fig. 788.—Ball Crushing Machine with Sieve.

The Alsing cylinders (Fig. 789), which may be of cast-iron or steel, are coated inside with a casing of millstone grit in which fragments of flint are incorporated. Flint pebbles or balls of granite or millstone grit are introduced into this casing. The cylinder, which moves on an axle, draws the balls along in its

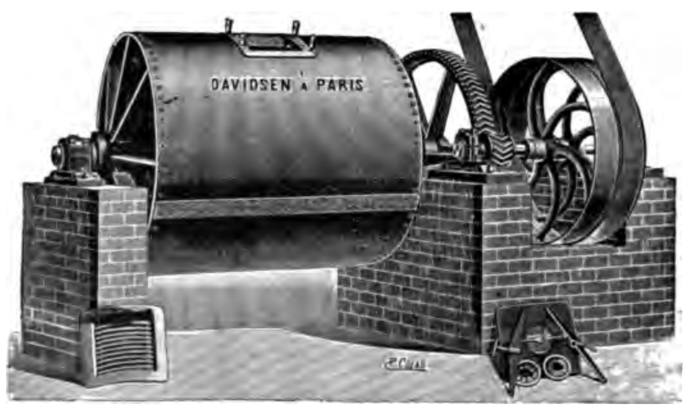


Fig. 789.—Alsing Crushing Cylinder.

rotation, and the resulting friction wears and pulverises the mass to be crushed. The crushing may be effected on the substances when either dry or moist. The opening through which the substances to be crushed are introduced is closed by a stopper (to the right of the figure), and when the operation is finished this is replaced by a grating (to the left of the figure)

which allows the crushed substance to pass but retains the balls.

When the clay is crushed in presence of water, it is afterwards passed through the filter press, and thence to the oven; when it is sufficiently dried, it is mixed with the other substances required to form the paste.

If the crushing takes place on dry clay, the powder is damped in the proper machines (p. 64) and is then mixed with the other materials. The required quantity of metallic oxides is

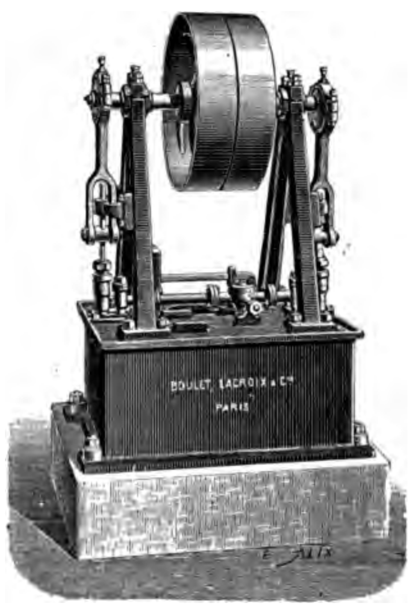


Fig. 790.—Pump for Hydraulic Press.

afterwards added to the pastes, if they are to be coloured, and the mixtures, closely blended together, are placed in pigeon-holes within reach of the workwomen who are to perform the moulding.

Moulding of Plain Quarries.—This is effected by compressing the powdered mixtures in metallic moulds with powerful hydraulic presses worked in different ways. Some have a revolving table (Fig. 791), and the water, compressed by a steam pump (Fig. 790), acts directly, or through accumulators, which is preferable for the uniformity of the products.

The table bearing the moulds, three or four in number, is turned by hand or with a small pump round one of the uprights of the press, in such a way that the compression of one empties the one just pressed, and a third is meanwhile being prepared. The compression is transmitted from the pumps or accumulators

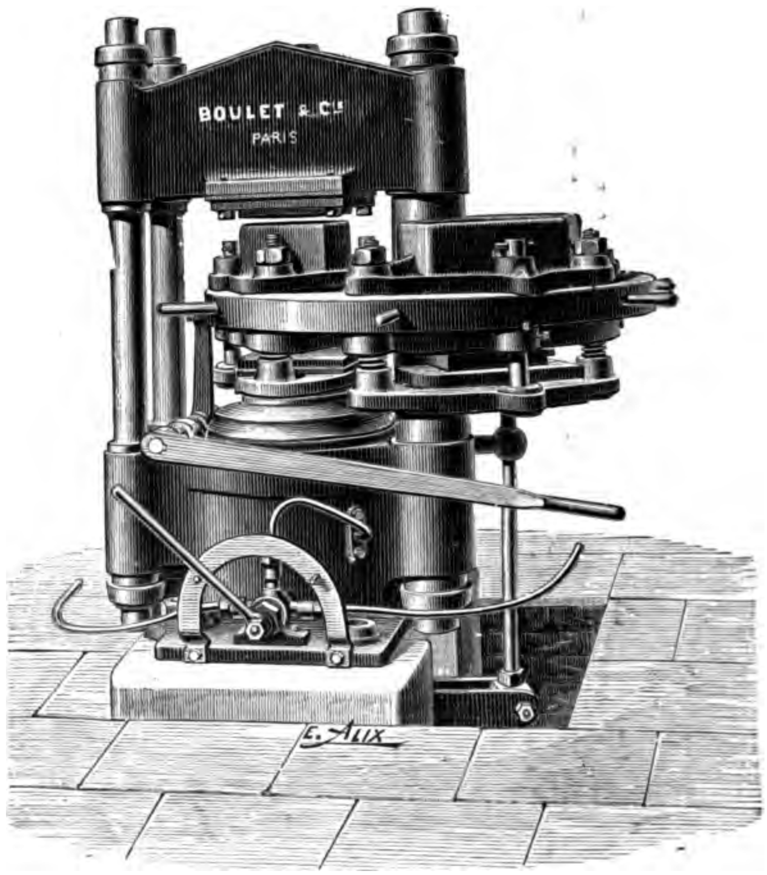


Fig. 791.—Hydraulic Press (Boulet).

to the press by a distributer provided with a lever. Two accumulators are often used, one of which gives the low pressure (50 to 80 atmospheres) and the other the high pressure (200 to 250 atmospheres). One accumulator serves for four or five presses, but two will be required if both pressures are used.

The full mould is placed upon the piston, and the workman,

by moving the lever of the distributers, gives the lower pressure in order to expel the air from between the grains of the powder. If this precaution were not taken, the bubbles of air disturbed by the pressure would accumulate in a horizontal plane; in the firing, they would become heated and would cause accidents, especially in insufficiently baked quarries. At the proper moment, therefore, this air must be allowed to escape, and then the high pressure is applied by means of the distributers.

When the quarry is finished, a workman withdraws it while another full mould is pushed over the piston. The distributer is turned to low pressure; the piston, by means of a series of

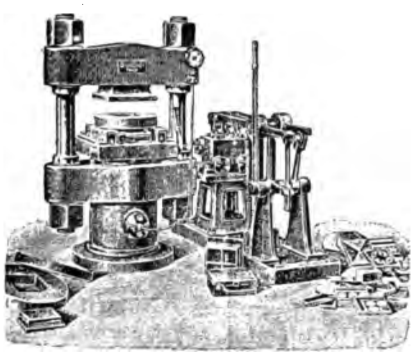


Fig. 792.—Hydraulic Press with Distributer and Accumulator (Laeis et Cie.).

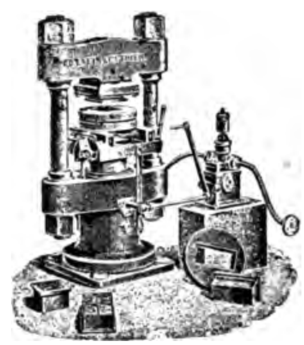


Fig. 793.—Hydraulic Press with Pump Distributer (Laeis et Cie.).

levers, sets in motion in its ascent the demoulder, which presses on the quarry previously pressed and expels it from the mould.

Working with accumulators and a single block, three workmen produce 180 quarries per hour; with double blocks, the production reaches 250 quarries. The direct action of the pump only allows of 140 quarries per hour.

Moulding of Incrusted Quarries.—This was the first object of manufacture with powdered clay. The pattern of the quarry is reproduced by means of a network of thin metallic bands soldered together, whose height is equal to the thickness of uncompressed incrustation (three to four inches). The cells thus formed receive the coloured powders. With the chambered network, thin metallic plates are prepared, in which are cut out

for the punch the parts of the pattern which are to be of a different colour; each colour then requires a plate whose openings correspond exactly to the hollows in the chambered frame (Figs. 794, 799). Each mould must have its own network and its different lids.

All the moulding pieces being previously prepared, the work is then divided; each colour requires a workwoman. In front of her is a compartment from which she draws the coloured mixture; the latter she puts into a small sieve, and, a lid (Fig. 795) having been placed over the network, the workwoman shakes the sieve over a funnel with which the mould is provided

Fig. 794.

Fig. 795.

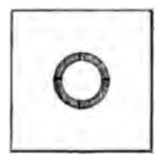
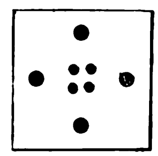


Fig. 796.



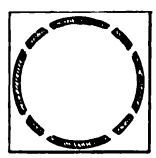


Fig. 797.

Fig. 798.

Fig. 799.

Figs. 794 to 799.—Networks for the Manufacture of Incrusted Quarries.

(Fig. 801); the pulverised clay falls, and fills the disclosed empty space. When it is full, the lid is taken off, and the mould passes to another workwoman, who puts on it another lid having an orifice corresponding to another colour (Fig. 796). This process is continued until all the colours are placed.

The moulds are made in two parts, which are placed one over the other; the lower part has the thickness of the uncompressed incrustation, and the upper part that of the paste. When the first has been filled as above described the caliber is removed, a slight pressure is applied with the hand or a mandrel, and the second part of the mould, filled with powdered ordinary clay, is put on. Chambered effects are produced by giving a

greater thickness to the copper blades composing the caliber. When this latter is removed, a hollow is left which is filled with a black paste, and then, a slight shaking motion having been

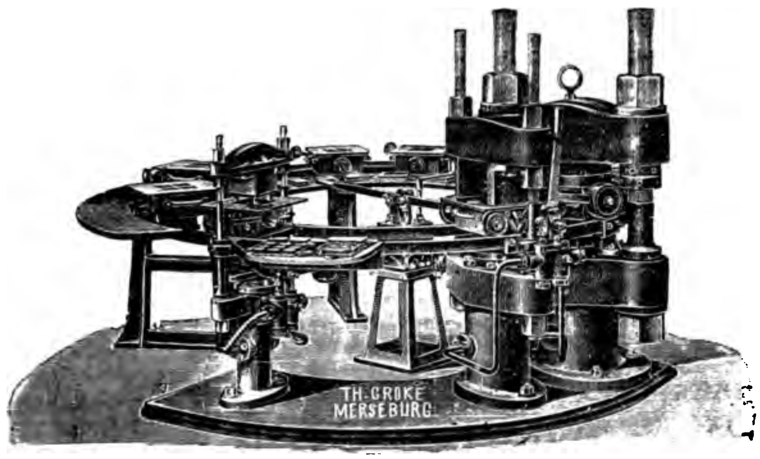


Fig. 800.—Press with Circular Table for Incrusted Quarries.

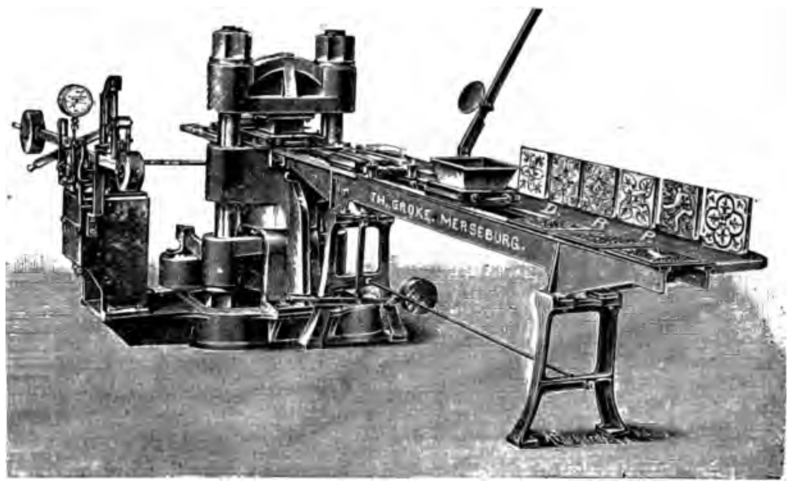


Fig. 801.—Press for Incrusted Quarries.

given to settle the powders, the filling is completed with ordinary paste, and the quarry is pressed.

For limited production the preceding presses may be used, or the one represented in Fig. 801 ; for large output, it is better to use presses with circular tables of large diameter (Fig. 800).

The moulds run on rails and pass in turn before the work-women who are to fill them. When the pattern is completed, the second part of the mould is placed over and filled; then the whole is pushed under the press. Removal from the mould is effected by means of a small hydraulic press.

Drying.—This is done in closed drying-rooms heated by the waste heat from the kilns; by hot-air stoves or steam when the first method is insufficient.

Firing.—The kilns used are intermittent and reverberatory, in the style of that described on p. 205 and the following pages.

Figs. 802 and 803 are the section and plan of a kiln of the same kind which is working in an important factory in the North of France. The furnaces are ten in number, the draught passes through the centre of the kiln, and the flames follow the course indicated by arrows. The quarries are packed with sand in large saggers; the stacking must be judiciously done, the quarries whose colouring oxides best resist the heat being placed in the hottest parts of the kiln. Care should be taken not to put in the same sagger quarries whose colours have different properties, etc. The fire, which is pushed gently at first, reaches its maximum at the end of the operation; the temperature is then from 1200° to 1400° C., sometimes as much as 1500° C., that of dazzling white. The consumption of coal depends upon its quality; as an average, we must allow 25,000 kilog. for a kiln which contains 40,000 kilog. of quarries, which represents 1000 square metres of pavement.

Continuous kilns with separate chambers, even those using gas, do not seem to give satisfactory results. A semi-continuity may, however, be established by arranging intermittent reverberatory kilns in a battery of four or six.

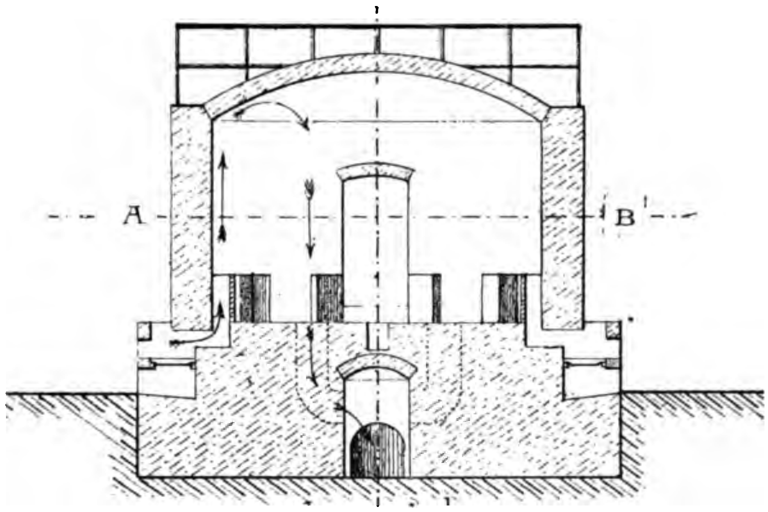
Applications.

The manufacture of stoneware quarries with powdered clay was introduced into France by Boch brothers in 1861. Their factory at Maubeuge was then under the direction of M. Simons,

REVERBERATORY KILN FOR STONEWARE QUARRIES.

Fig. 802.

Vertical Section through C D.



Horizontal Section through A B.

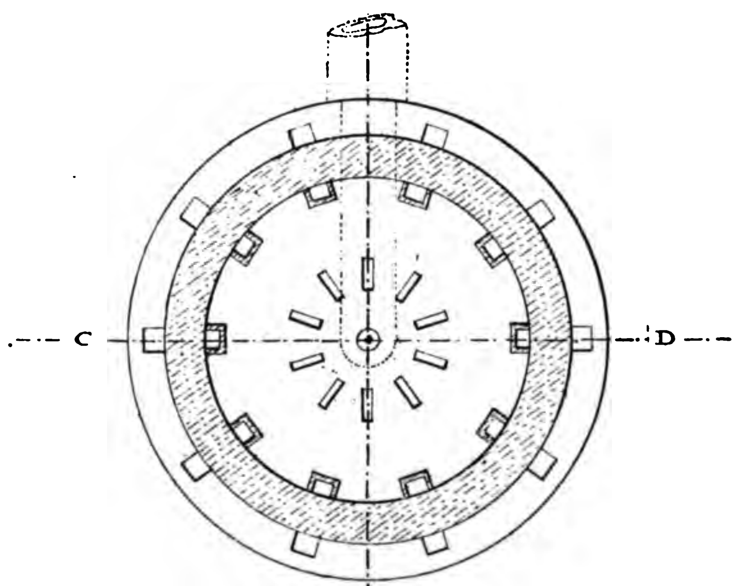
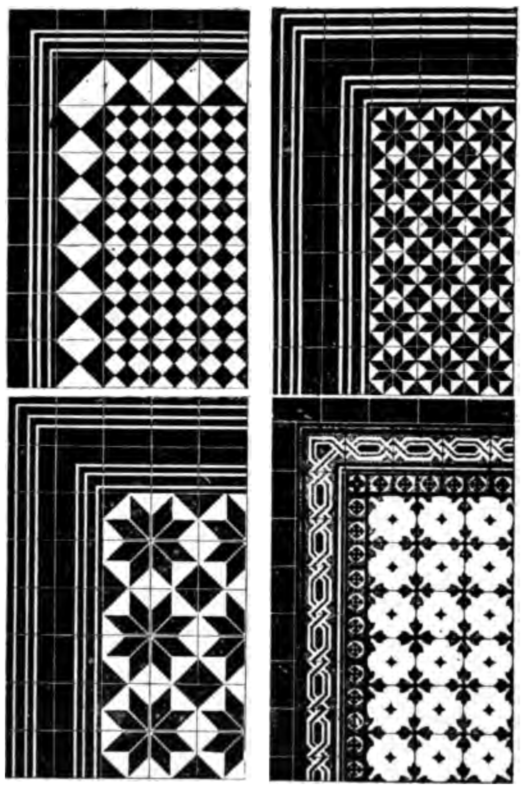


Fig. 803.

Fig. 802.—Section. Fig. 803.—Plan.

who retired from the firm in 1868 and founded, at Cateau, the factory which is at present managed by his sons. Two other managers of the Boch firm, MM. Sand and Charnoz, founded factories at Feignies and Paray-le-Monial respectively. To these four establishments another was added in 1882, that of M. van Overstraten de Smet at Canteleu-Lille. The firm of Perrusson fils et Desfontaines also makes incrusted quarries.

Fig. 804. Fig. 805. Fig. 806. Fig. 807



Figs. 804 to 807.—French Incrusted Quarries (Perrusson fils et Desfontaines).

The method of manufacture in the centre of France (Charnoz and Perrusson) differs from that of the North both as regards moulding and primary substances.

The principal centres of the manufacture of stoneware incrusted quarries abroad are at Saint-Ghislain (Cie. générale de produits céramiques) and at Chimay; in Spain, at Barcelona (Romeu Escofet), at Valence (Miguel Nolla); in Germany, at Mettlach (Villeroy and Boch), at Jingig, etc.

Generally speaking, the quarries made on the Continent are used like English quarries; only the patterns are different. The black and white squares are the simplest, and form geometrical (Figs. 804 to 806) or fancy patterns (Fig. 807). The

quarries with polychrome patterns are of less severe aspect and are arranged in different ways, the commonest being the

Fig. 808.

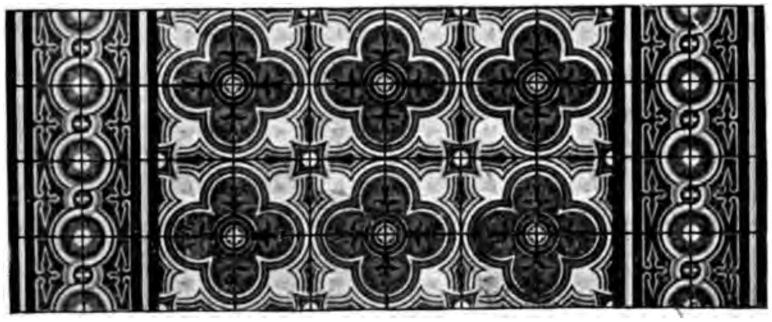
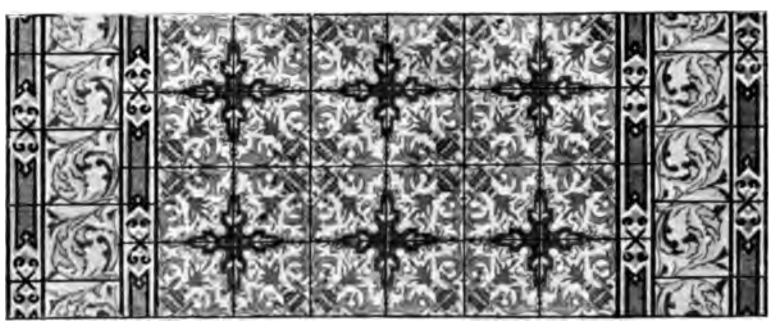


Fig. 809.

Fig. 810.



Figs. 808 to 810.—French Incrusted Quarries (De Smet et Cie.).

combination of four squares to produce roses (Fig. 808) or other decorative effects (Figs. 809, 810).

But a single quarry having a special pattern is sufficient to produce a large number of varied designs, as may be seen from


Fig. 812.


Fig. 815.

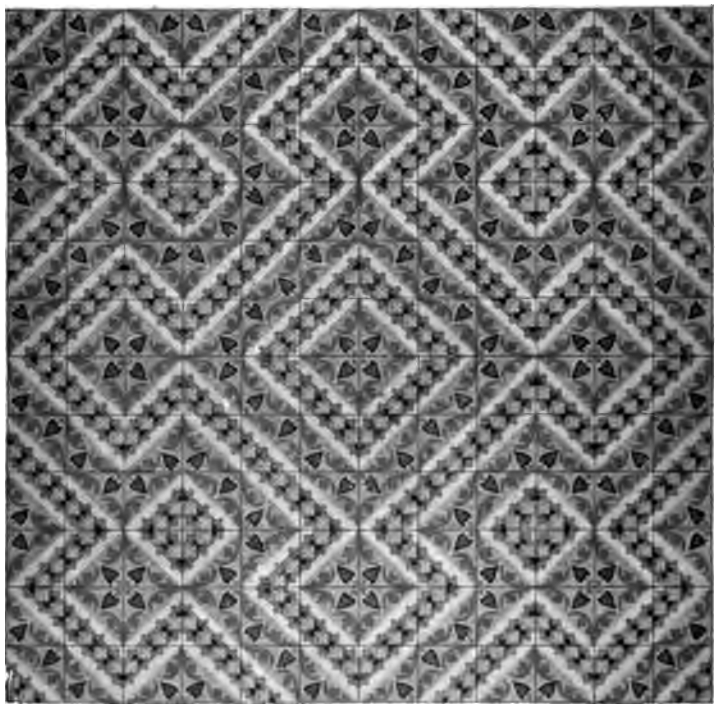


Fig. 814.

Figs. 811 to 815.—French Incrusted Quarries (Boch frères).

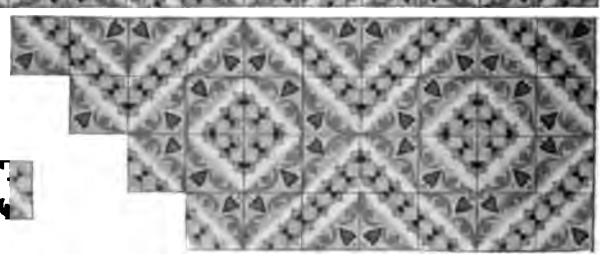


Fig. 813.


Fig. 811.

Figs. 813, 814, 815, which are produced with the quarry 811, 812.

As we might expect, we find in the Spanish quarries the influence of Arab ornamentations; the firm of Nolla, one of the most important of that country, also produces geometrical

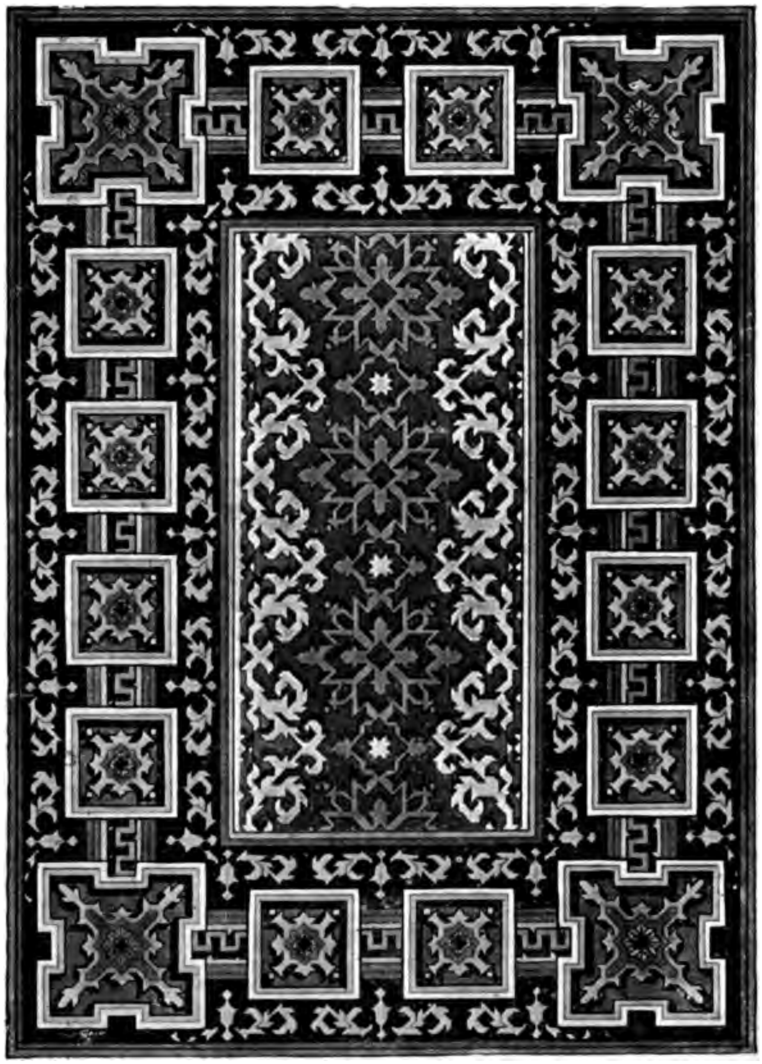


Fig. 816.—Mosaic of Incrusted Quarries (Spanish Manufacture of Miguel Nolla).

mosaics, with patterns inspired by the Renaissance (Fig. 816) and even by Persian art.

The use of mosaics in stoneware, so extensive in England,

is beginning to extend in France, in which country they made their first appearance only about ten years ago. Besides their variety of colour, they have the advantage of very great durability. They may be of geometrical pattern (Fig. 818) or display concentric circles of uniform (Fig. 820) or varied colour (Fig. 819), adorned with arabesques or flowers.

Fig. 817.

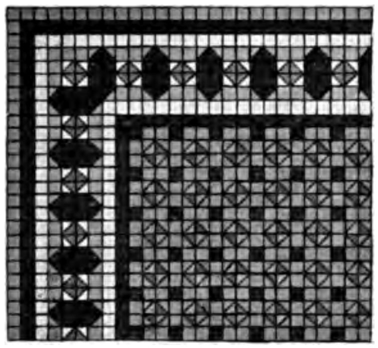


Fig. 818.

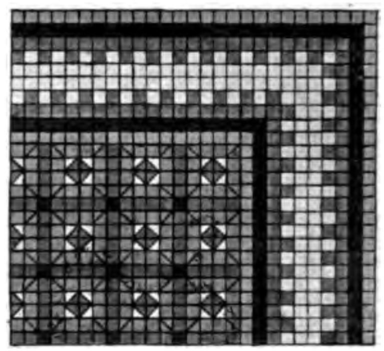


Fig. 819.

Fig. 820.

Figs. 817 to 820.—Stoneware Mosaics (De Smet et Cie.).

Geometrical mosaics are formed of little cubes of different colours, which are made by special machines; the others are executed from fragments of different dimensions and shapes obtained by breaking plain stoneware quarries. In laying down mosaics we must avoid leaving crevices; this is done by the use of old half-softened cement; besides, manu-

facturers undertake the laying down of their products themselves.

The price per square metre of pavements of incrusted stoneware (not including laying, which costs from 4 to 6 francs the metre) varies from 10 to 20 francs for the best quality and from 7 to 14 francs for second quality.

Stoneware mosaic pavements cost from 25 to 300 francs per square metre (laying included) according to the richness of the pattern.

II. FACING QUARRIES.

Paving quarries are not glazed. It is true that in the Middle Ages varnish was used to protect the patterns, and that faïence pavements were fashionable during the 16th and 17th centuries, but these are exceptions which should not be imitated, as the slippery surface of these quarries makes them dangerous. Their use, however, is distinctly indicated for the facing and artistic ornamentation of walls.

Facing quarries are divided, according to the nature of their paste, into—

1. Faïence quarries;
2. Stoneware quarries;
3. Porcelain quarries.

1. Faïence Quarries.

The word "faïence," first applied only to enamelled terra-cotta, has been since extended to ceramic products which are not enamelled terra-cottas, such as those English flint-wares which are made of white paste formed of kaolin, flint, and felspar, and have colourless glaze. This same paste is much used in these days for making quarries which afterwards receive different kinds of decoration, and are called faïence quarries from their resemblance to the old quarries of enamelled clay. We must then class quarries according to their composition and distinguish between—

A. Quarries of limestone paste (stanniferous faïence) ;
B. Quarries of silica paste (Persian faïence);
C. Quarries of felspar paste (flint-ware, iron-clay, etc.).

A. QUARRIES OF LIMESTONE PASTE.

These receive stanniferous enamels which require the presence of lime in the paste in order that there may be harmony between the two. We give as examples three formulæ for Paris faïence—

Bastenaire-Daudenart.—White clay or calcareous marl from the Combat pit	12
Green clay from the same pit	12
Yellow clay (Picpus pit)	10
Arcueil clay (Fontainebleau pit)	6
Brongniart.—Plastic Arcueil clay	8
Greenish clay-marl	36
White calcareous marl	28
Yellowish marly sand	28
Salvetat.—Green Fresnes clay	37.5
White marl	30
Picpus fireclay	20
Fontenay sand	8
Gentilly clay	2.5

The clays are prepared as usual by blending; each manufacturer has his own special processes according to the clays he has to treat. The quarries are moulded by hand in plaster moulds which have the pattern, if there is one, in hollow or relief on them. Presses may also be used.

The glaze for these quarries, which is always stanniferous and consequently opaque, has the white enamel as its base. The processes described in the general remarks on glazes may be used for their decoration, but the method most frequently employed is decoration on unfired enamel. In this way are made the thousands of common squares used for facing kitchen ranges, and, in France, principally manufactured at Ponchon (Oise) and Desvres (Pas-de-Calais).

The white enamel is spread over the quarry by immersion, and after drying the pattern is printed by means of a cut-out

engraving or a stencil-plate over which a hard brush covered with the enamel paste is rapidly passed.

If the pattern includes beads, they are made by hand. This process, called "au pochoir," is carried out with extraordinary rapidity by highly-skilled workmen, and they succeed in producing quarries which can be sold finished, at seven francs a hundred or even less.

The decoration is monochrome, but it can be enriched with other colours either by the brush, or by the usual processes.

For outer facings, the quarries have a greater thickness; the unenamelled side, which is placed against the wall, bears hollows intended to increase the adhesiveness of the mortar.

B. QUARRIES OF SILICA PASTE.

This paste is the base of the Deck faïences, whose brilliancy and decorative effects are comparable to the finest ancient Persian faïences, and which are now freely manufactured, thanks to the generosity of the inventors in publishing their processes. The paste is prepared by crushing in a dry state a frit composed of: 85 parts of Fontainebleau sand, 7 parts of carbonate of potassium, 3 parts of carbonate of soda, and 5 parts of chalk. To 15 parts of this frit are added 25 parts of refractory white clay and 60 parts of flint. The addition of 6 to 8 parts of chalk gives a harder clay, more easily cut but more liable to lose shape in firing. The paste is white, not very plastic, and is difficult of treatment, which is not an obstacle since it is intended for small smooth surfaces; its total contraction may be as much as 2 per cent.

The quarries are moulded by hand or in the press; after drying they are fired, and if necessary finished on the grindstone. Although they are white, they are dipped to give more delicacy to the colours and to render the biscuit less absorbent, thus permitting of greater uniformity of colouring. The manufacture is more troublesome, but the results are much superior.

The dip is composed of 75 parts of frit, 15 parts of chalk, and 10 parts of white clay, to give it a little pliability; the whole is

crushed fine and diluted with water to the required consistency. The dip is applied by dipping or sprinkling, and is fixed by firing; it is then decorated with finely ground colours diluted in the muller with a little gum arabic. These are applied with the brush, each tint in turn, avoiding impastes, which the glaze would not be able to dissolve and which would give a dull appearance. The piece is then covered with a glaze, crushed not too fine in a dry state, and containing—

	Deck.		Sèvres.
Minium	30	30	38
Sand	48	50	38
Carbonate of potassium	12	12	15
Carbonate of sodium	10	8	9

The temperature of firing is about 1000° to 2000° C.

C. QUARRIES OF FELSPAR BASE.

This is the paste of the English flint-wares; its composition varies within certain limits, but usually it contains—

From 20 to 45 per cent. of white plastic clay, which serves as a binding substance;
From 25 to 45 per cent. of kaolin, to prevent the paste from turning yellow in firing;
From 20 to 40 per cent. of flint, which shortens and gives whiteness and durability;
From 5 to 15 per cent. of pegmatite or felspar, which acts as a flux.

The clays are always washed to separate the coarse parts; the flint is heated in kilns and then crushed, and the felspar is also pulverised. The purified substances are diluted in a volume of water so measured that they shall have the same degree of consistency, and then a calculated quantity of each paste is poured into a vat, in which the mixture is effected by stirring. After this, the paste is filtered through fine brass wire sieves which are shaken by machinery; the filtered portion is sent to the filter press and thence to the cellar to solidify.

Moulding, in the case of small output, is done by hand; for larger quantities machines working on firm or dry paste are used. In this case the paste, when it comes from the filter press, is

carried to hot-air drying-rooms, and is then blended and reduced to powder in a centrifugal pulveriser. The two operations are performed by the same machine (Fig. 821).

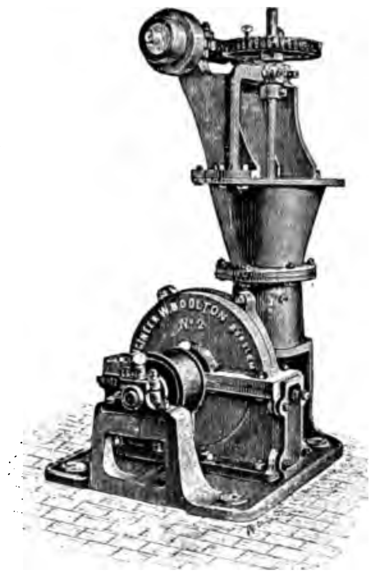


Fig. 821.—Centrifugal Pulveriser.

The powder is afterwards placed in a metallic mould and compressed in a press similar to those described on p. 433.

The quarry may be decorated in various ways. In the case of plain glazed quarries, a boracic plumbiferous alkaline glaze is used ; some formulæ are appended (Pressel).

	Composition of the Frit.							Composition of the Glaze.						
Boric acid	...	17	...	18.5	15	...	18							
Borate of soda (borax)	35	...	30	...	...	32	...							
Carbonate of soda (crystals)	...	22	...	23.5	16	...	20	23 of felspar.						
Carbonate of lime (chalk)	18	17	...	15	13	...	16	...	...	...	...	...	11.5	...
Carbonate of lead (white lead)	...	...	...	...	...	...	...	18	21	12	18	6	18.5	22
Kaolin	12	15	11	8	11	3	13							
Plumbate of lead (minium)	...	...	...	...	19	...	...							
Pegmatite	...	...	31	25	...	41	...	30	31	8	22	...	11	18
Sand	35	28	17	10	26	24	32	...	...	6	...	...	...	3
Frit	...	...	...	...	...	...	...	52	47	74	60	70	59	60

The glaze is applied by one of the processes mentioned in the general remarks on glazing (immersion, insufflation).

When the quarries are to receive a pattern in relief, the outlines are impressed on the clay when still fresh by stamping in plaster moulds; in ordinary patterns the outline is marked out in black lines, and in both cases the spaces between the lines are fitted in with enamels, generally transparent. This is what is wrongly called cloisonné decoration.

When a large number of quarries are decorated with the same monochrome pattern, copper-plate printing is used, and for polychrome decoration chromolithographic printing. This decoration is performed over glaze, and sometimes under glaze.

Besides, we may use, according to the effects required, one or other of the processes mentioned in the general remarks on the decoration of pottery. The quarries of which decorative panels, intended for the facing of walls, are formed are most frequently covered with transparent enamels.

Firing of the Quarries.—This is in two parts: the firing of the paste and the firing of the decoration; sometimes even there is an intermediate firing for the glaze or dip, which is placed upon the biscuit and fixed before decoration.

Each manufacturer has his favourite kiln, so to speak, for firing the pastes; many direct-flame kilns are still to be found, although reverberatory kilns are increasing in popularity. The stacking is done in many ways, and most frequently without any precaution, so that the quarries receive the indirect action of the flame. Thus in the case of faïences with stanniferous enamels, they are arranged in parallel rows and the quarries are separated from one another by little pieces of refractory clay with angular and pointed surfaces called "spurs."

The consumption of fuel depends upon the nature of the objects fired; the aim of the manufacturer will be to make the best possible use of his kiln by means of a judicous stacking of the products. On account of the numerous hollows, the expense of fuel varies very little whatever the weight of the stacked products may be, and is about 80 to 100 kilog. per cubic metre.

The temperature of firing depends upon the composition of the pastes, and rises to about 1000° to 1200° C.

The firing of the decoration depends upon the process and the nature of the substances used. The stanniferous enamels used for the common quarries of Ponchon or Desvres are stacked in loads without special precautions.

Artistically decorated quarries naturally require more care; we must employ either saggers or stacking "par échappade," which consists in dividing the kiln into a series of divisions by means of refractory products in the shape of slabs resting on supports placed by the quarries and higher than them.

MUFFLED KILNS.

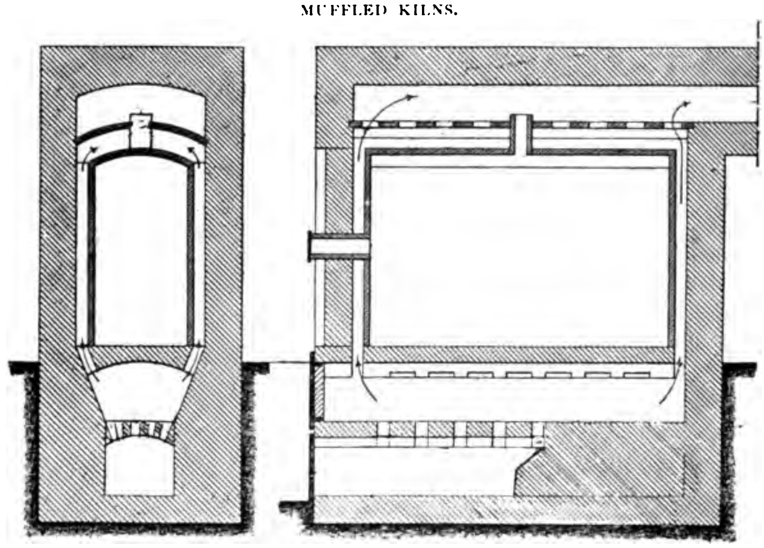


Fig. 822.—Cross Section. Fig. 823.—Longitudinal Section.

The temperature necessary for vitrifying glazes is very variable. The enamels for Deck's silicious faïence bear up to 1200° C.; stanniferous enamels also resist great heat if they do not contain too much lead, but over-glaze decoration requires a lower temperature: 700° to 800° C.

Many of these decorations cannot bear contact with the gases of combustion, and are fired in muffled kilns. Muffled kilns consist of a firing chamber round which the flames and gases of combustion circulate without ever penetrating into the interior.

The stacking is done through one side of the chamber, which is afterwards built up with a clay mortar. A wall is built at a certain distance from the kiln to enclose the space in which combustion takes place (Figs. 822, 823).

The expanded air of the firing chamber escapes through an opening which communicates with the upper air-channel and in front. Another opening allows of the degree of firing being observed. The temperature which can be attained in a muffled kiln does not exceed 1000° to 1100° C. at most, and is generally much less.

2. Quarries of Glazed Stoneware.

Manufacture.—They are made in the same way as paving quarries, and with the same substances, machines, and kilns.

Glazing.—The glaze with which these quarries are covered is always colourless. It is applied in various ways, more commonly by salting, as in the case of pipes, by throwing sea-salt into the kiln when "en grand feu"; its nature is then silico-alkaline

Lead glazes are still used, and are applied by volatilisation in the following manner. The inside of the saggers is coated with a mixture of: sea-salt, 67 parts; carbonate of potash, 28 parts; minium, 5 parts. The heat volatilises these substances, and they condense on the quarries and attack their surface, forming a multiple silicate which forms the glaze. The silica is taken from the stoneware, which is always very rich in it.

Other glazes are also used which contain more lead and vitrify at a lower temperature, but which require a second firing. Here are two formulæ—

	Glaze I.	*Frit for Glaze II.*		
Melted borax	15	...	Frit	100
Carbonate of lime	...	15	Carbonate of lead	35
,, potash	5	...	Felspar	50
,, soda	...	30		
Felspar	35	15		
Kaolin	...	10		
Minium	20	..		
Quartz sand	25	30		

The glazes are ground and diluted with water; they are applied by sprinkling or immersion. When the paste of the stoneware is slightly yellow, the colour is disguised by lightly tinting the glaze blue with oxide of cobalt.

3. Porcelain Quarries.

The East and especially the far East makes great use of porcelain quarries and plates for the ornamentation of walls; this substance does not, however, appear to be used in Europe for that purpose. Besides, felspar faïence fulfils the same purpose in a more economical manner.

Application of Facing Quarries.

The applications of these quarries are extremely diverse; we will pass over quarries for the outside facing of buildings, as these belong rather to the category of decorated terra-cottas, and we will confine ourselves to quarries which are used on interiors.

Common faïence quarries with stanniferous enamels, called Ponchon or Desvres (Figs. 824 to 831), are used especially for facing the walls above kitchen ranges and for adorning these ranges. The most common types of these applications are represented in Figs. 827 and 829.

The quarries of felspar faïence compete seriously with the foregoing ones; their patterns are of a higher class (see the different styles: Figs 833, 834, 836), and their colours are more varied. These quarries are used for mantelpieces, in which their appearance is less monotonous than that of white panels.

Bathroom quarries are also made in felspar faïence, and sometimes of glazed white stoneware. Figs. 848 to 850 represent applications of this class of facings.

The preceding quarries are currently manufactured and have not a very decorative appearance, but for higher-class wall

Fig. 824.

Fig. 825.

Fig. 826.

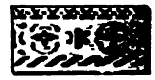


Fig. 827.

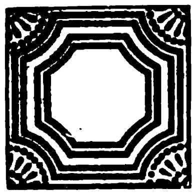


Fig. 828.

Fig. 829.

Fig. 830.

Fig. 831.

Fig. 832.

Figs. 824 to 832.—Desvres Faience Quarries (Fourmaintraux-Courquin).

Fig. 833.

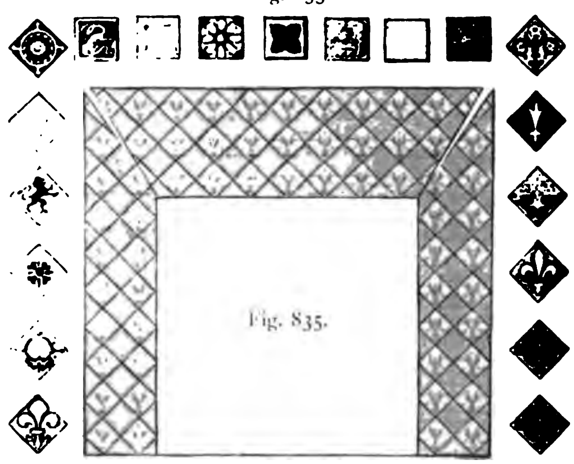
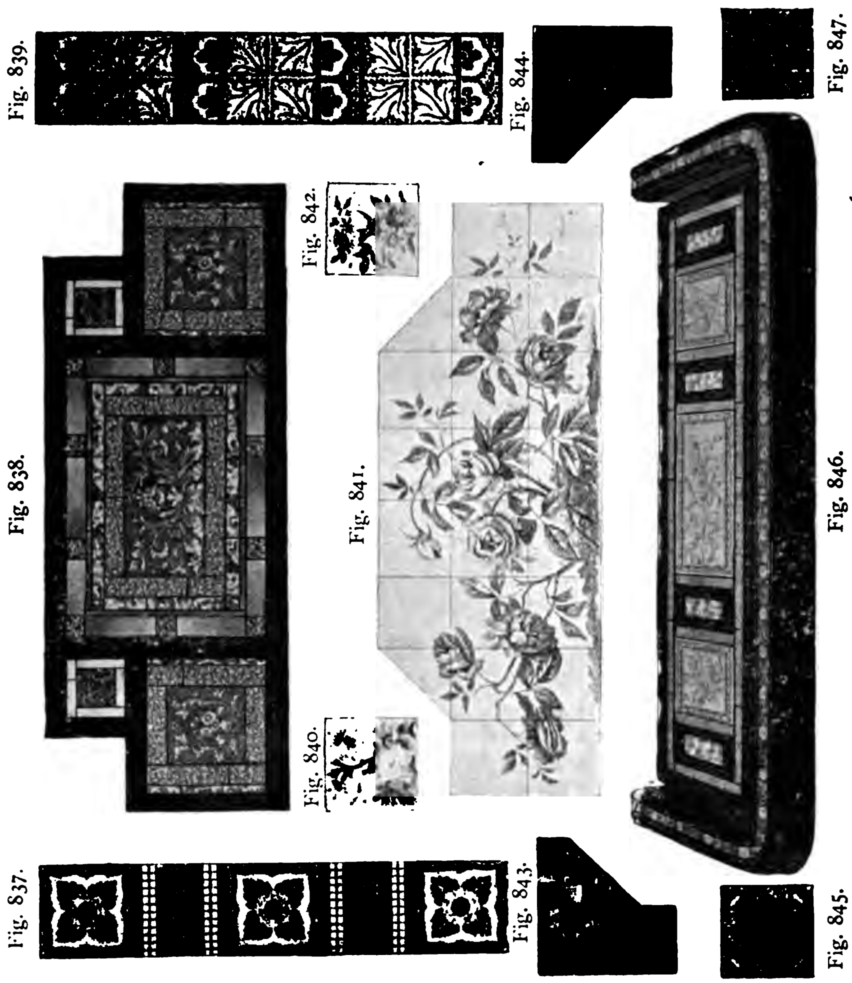


Fig. 834. Fig. 836.

Figs. 833 to 836. - Faience Quarries and Mantelpiece executed with these Quarries (D'Huart frères).

ornamentation quarries are made which represent artistic compositions and are sometimes of real value.

Plate III. represents "Jewellery," a large panel executed by



Figs. 837 to 847.—Decorated Quarries (Hearth and Panel Tiles by Woolliscroft & Son).

Deck from the sketches of Ehrmann, which appeared at the Exhibition at Amsterdam in 1883.

Quite another style is represented by Plate IV.; this is a graceful composition executed by the faïence factory of Creil and Montereau for the Saintes Library.

Plate V. shows another rustic scene, and is of pleasing effect;

the panel is formed of squares of 16 centimetres side, and was executed by MM. D'Huart frères of Longwy.

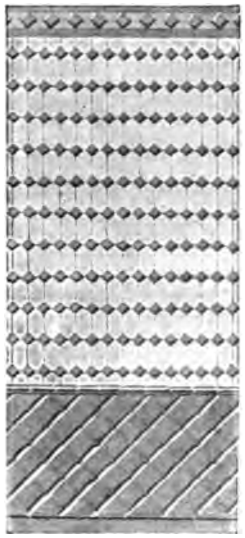


Fig. 848.

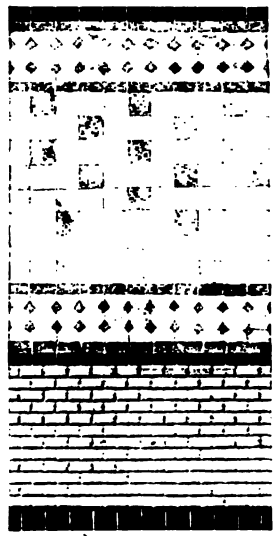


Fig. 849.

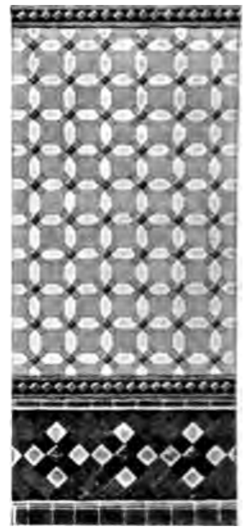


Fig. 850.

Figs. 848 to 850.—Facings of Ceramic Quarries (D'Huart frères).

III. STOVE QUARRIES—CHIMNEY-PIECE FAÏENCES.

The manufacture of these faïences has shown great development, not only in Germany, the country of its origin, but also in France, where, according to Deck, a good judge in these matters, it has had a great influence on work connected with faïences.

Quarries and Panels for Stoves.—These products should, without splitting, resist a heat which is uneven, and most frequently suddenly kindled. For this purpose a paste was used whose somewhat loose physical texture is favourable to expansion. This porous paste, covered with a dip or not, was simply glazed.

When Hirchvogel began the manufacture of enamelled faïence stoves at Nuremberg, another difficulty presented itself; the enamel applied to the paste cracked. It is true that, in

Switzerland and Germany, stove quarries which did not crack were made with fine calcareous clay containing naturally all the elements of an uncrackable paste, but it was impossible to manufacture large panels which would bear heat without splitting. They fell then from one defect into another; either the faïence cracked or it split. As this latter inconvenience is more serious than the former, the lesser evil was chosen, and for a long time cracked faïence was used. At that time only stoves in white faïence and of small size were manufactured.

It was in 1840 that Pichenot, a Parisian stovemaker, and his son-in-law Lœbnitz succeeded in obtaining a clay suitable for making large pieces in which the enamel would not crack; this was the beginning of that faïence panel industry which was to stimulate so greatly the progress of pottery.

When Pichenot and Lœbnitz had patented their invention, attempts were made to pirate it. Instead of using lime in the form of chalk, as the inventors did, marly sands were employed. Proceedings were taken which, on appeal, ended in favour of Pichenot and Lœbnitz. Having mentioned this as a historical fact, we will compare the two formulæ which were the subject of contention.

Pichenot Formula.		*Barral Formula.*	
Vaugirard plastic clay	25	Gentilly plastic clay	32
Meudon chalk	25	*Ivry sandy marl*	38
Belleville sand	13		
Cement made from fragments of saggers	37	Cement made from pottery	30

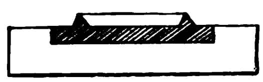
In Germany, where stove quarries are extensively manufactured, Velten clay is used; this, according to Seger, contains on an average 45 per cent. of silica, 11 per cent. of alumina, 5 per cent. of oxide of iron, 16 per cent. of lime, 1.5 per cent. of magnesium, 4 per cent. of alkali, and 16 per cent. of water and carbonic acid.

Preparation of the Pastes.—The clays are carefully chosen and the cement is prepared by crushing, but not too finely, the fragments of saggers or other pieces (for it is not always advisable that the cement should be refractory) in one of the mills previously described (p. 57).

The whole is blended in pug-mills, and the paste, after being made sufficiently homogeneous and plastic, is put into parallelopiped or slab shape and carried to the moulding-room to be transformed into quarries or panels of different sizes.

Moulding.—Plain panels are made by cutting off a slab of the proper thickness from the parallelopiped of clay which must have a base equal in size to the largest plate required; the cake is taken up between two rulers in order to avoid tearing it, and is placed in a plaster mould (Fig. 851) which has the dimensions of the piece to be made; then it is pressed with the hand as evenly as possible, and the excess of clay which projects over the sides of the mould is removed with an iron scraper. In order to support the plate and keep it true, "colombins" made of the same paste are welded to it. After being removed from the mould, it is carried to drying-rooms heated by the waste heat of the kilns or by any other means.

Fig. 851.



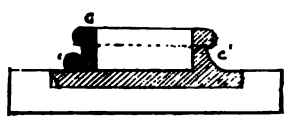


Fig. 852.

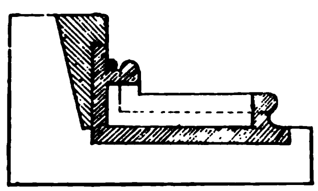


Fig. 853.

Figs. 851 to 853. Moulding of Stove Quarries.

The surface of the slab is either plain or has ornamentation in relief moulded on it by the hollows of the plaster mould. In the case of flanged quarries the process is a little more complicated. A colombin made by expression (Fig. 852) and having sections represented by C, is welded round the edges of the plate, which has been moulded as described above.

The attachment is strengthened by a small round colombin *c*, which is flattened to the fillet shape *c'*. In the case of angle or corner quarries, the mould is in two pieces to facilitate removal of the plate from it (Fig. 853).

The welding together of the colombin and the previously prepared slab may be mechanically effected by a special press (Fig. 855). The slab and the colombin are placed in a mould; a mandrel which has the shape of the inner hollow of the quarry

is lowered by means of a flywheel, and pressure being exerted by two lateral screws, the welding is automatically performed. Direct moulding in a press without previous rough fashioning does not give good results.

Drying should take place slowly, and it is often necessary to trim the surfaces of the quarries, when the paste has hardened, by striking them gently against a flat surface in the case of flat quarries, and against two surfaces at right angles in the case of angular quarries.

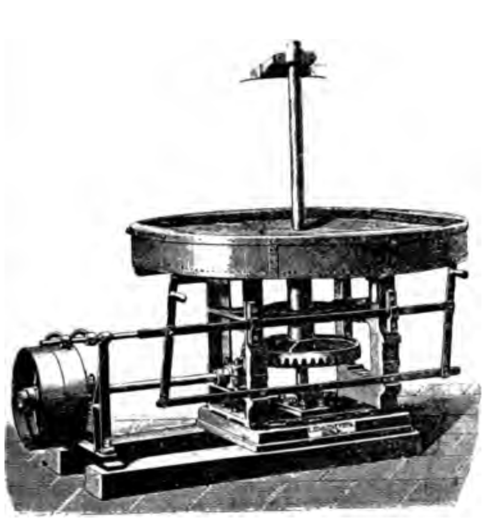


Fig. 854.—Machine for trimming Stove Quarries.

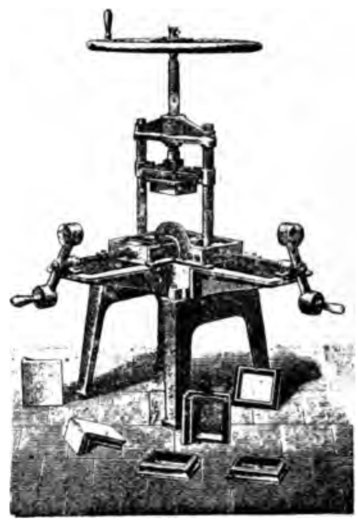


Fig. 855.—Press for welding Stove Quarries (Schlickeysen).

Stacking in the Kiln and Firing.—Quarries should be stacked so as to occupy as little space as possible. The kilns may be direct-draught or reverberatory. The quarries when fired are trimmed on the grindstone, or with a special machine, which consists of a large horizontal cast-iron wheel, covered with damped polishing sand. The facing side of the quarries is applied to the grindstone.

Enamelling.—*Decoration.*—The enamel used is always stanniferous, and is of the same composition as the one described for faïence quarries. The German enamels are more

alkaline than the French, as will be seen from the subjoined analyses—

Alumina	4.90	4.24
Lime	1.36	2.58
Oxide of tin	14.00	9.24
Oxide of lead	26.75	32.12
Potash	1.94	0.67
Silica	46.70	46.20
Soda	4.35	4.95

The enamelling is effected by immersion or sprinkling, and the products undergo their second firing either bare or in saggers with the precautions already indicated for enamelled pieces.

For a long time white enamel was the one most used, but for the last few years various darker tints such as green, brown, blue-grey, or greenish have been applied; they are obtained by means of stanniferous opaque enamels, or transparent coloured enamels, laid over dips. The stones have been given an architectural style (Figs. 856 to 860), imitated or modernised from ancient forms.

Applications.—Figs. 856 to 860 represent some types of stoves manufactured by the firm of Lœbnitz. The Renaissance stove (Fig. 857) is faced with quarries; the angles and cornice are formed of moulded pieces. The Gothic stove (Fig. 859) is also formed of a collection of quarries; the other decorative parts are moulded and afterwards enamelled.

The usual stove of Parisian dining-rooms is shown in Fig. 858; it is formed of straight panels curved for angles, supported by braces of polished copper. The base of these stoves is generally split, and this is due, not to the composition of the faïence, but to the method of putting together the stoves. A certain amount of play should be given to allow for expansion. But all the pieces are fitted closely together in order to get a fine appearance; hence ruptures occur.

Faïence Panels for Mantelpieces.—These are plates which form the frame of fireplaces; they are made like the preceding quarries. They may be white or decorated. The simplest are plain, and usually enamelled in white; other and richer ones have

more or less artistic decorations in colour, executed upon unbleached enamel. Figs. 861, 862, and 863 show different

Fig. 856.

Fig. 857.

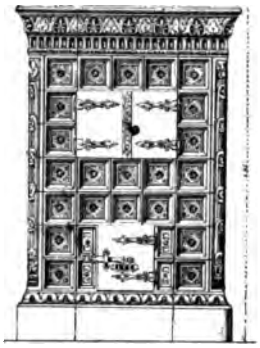


Fig. 858.

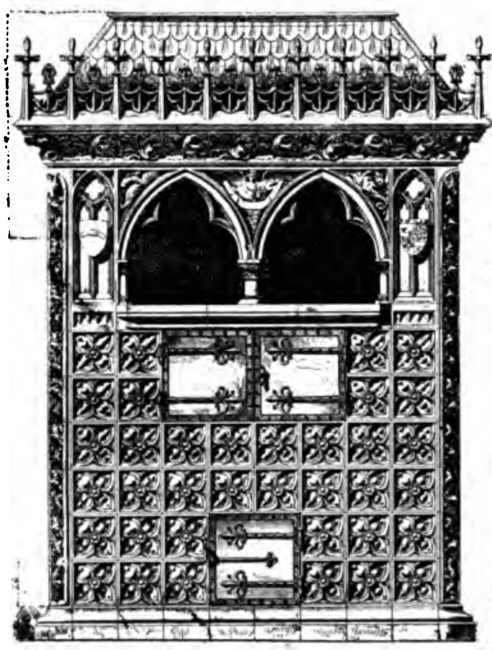


Fig. 859.

Fig. 860.

Figs. 856 to 860.—Decorative Stoves, Lœbnitz Types.

panels of this kind from the workshops of the well-known faïence stove-maker, M. Lœbnitz.

Another economical style of decoration has been introduced

by the same manufacturer. It is obtained by a special moulded embossment; to this embossment are applied enamels of light

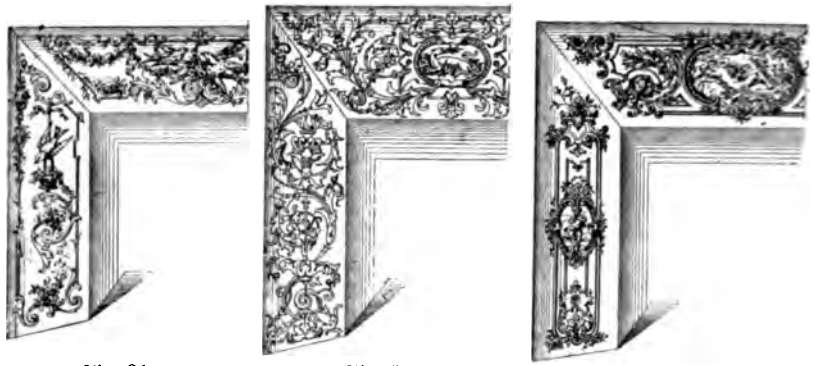


Fig. 861. Fig. 862. Fig. 863.

Figs. 861 to 863.—Decorated Panels for Mantelpieces.

Fig. 864.—Terra-cotta Chimney-piece with Embossed Panels (Loebnitz).

and dark brown, or other colours, which harmonise with the general decoration of the piece (Fig. 864).

CHAPTER IV.

ARCHITECTURAL DECORATED POTTERY (FAÏENCES, STONEWARES, PORCELAINS).

UNDER this heading are placed those glazed terra-cotta products which are used for architectural ornamentation, and which are distinguished by their shape from enamelled bricks.

The birthplace of this style of decoration, as of many other arts, was the East. The Assyrians and the Persians, probably also the Chinese, were the first peoples who applied enamelled products to the ornamentation of buildings. The Egyptians used glazes for their vases, but do not appear to have used them in their edifices.

After having disappeared, under the Greeks and Romans, for several hundred years, this style of decoration was again in favour during the 10th century in the East, and afterwards in Europe from the 12th century until the 16th, when it once more fell into comparative neglect. These ornaments regained their popularity in the 19th century in certain countries, for instance in Switzerland, Germany, England.

In France, there is also a movement in their favour, but of a more tentative nature.

Speaking generally, all potteries can be enamelled; all that is required is that the paste and glaze should harmonise, so that crazing may be avoided.

The composition of the glazes depends upon the nature of the clay.

The latter may have the composition of faïence, of stoneware, or of porcelain; hence the products are of three classes.

§ 1. FAÏENCES.

The paste used is somewhat fusible; it is coloured pale yellow or pink, more rarely white. According to the effects required it is covered: (1) with colourless transparent glazes (varnishes), which are placed either directly on the paste or over a dip; (2) with coloured transparent glazes (transparent enamels); and (3) with white or coloured opaque glazes (opaque enamels). The three kinds of glaze may be used together, and thus the preceding effects increased and varied.

The varnishes, which are generally plumbiferous, contain on an average 50 to 60 per cent. of oxide of lead with 40 to 50 per cent. of silica, those containing most lead being suitable for the most silicious pastes.

The transparent enamels are prepared with the foregoing varnishes to which are added from .5 to 5 per cent., according to the intensity of colour desired, of colouring oxides. If several varnishes are used together, care must be taken that they melt at the same temperature; this result is obtained by varying the quantity of silica, or by introducing alkalies.

It must be noted that the presence of the metallic oxides modifies the fusibility of simple glazes.

The opaque enamels are most used, because they allow of the colour of the clay being masked. The paste must be calcareous in order that they may harmonise with it. The fluxes used are the oxide of lead, boric acid, and the alkalies; the oxide of tin acts as an opaque substance, and the quantity of it used depends upon the colouring of the paste. Above all, the composition must be such that there are: (1) complete harmony between the paste and the glaze, in order to avoid crazing or scaling; (2) penetration of the glaze into the paste, to ensure a solid coherence between the two substances.

To satisfy the first condition, we have only to fulfil the laws relating to glazes (p. 394). The second is satisfied by noting the mutual action of the substances upon one another, for instance: to place an alkaline (basic) glaze upon a silicious (acid) paste,

and, conversely, a silicious (acid) glaze upon an aluminous (basic) paste, for under these conditions there is a chemical combination between the elements of the glaze and those of the paste. As regards physical properties, the paste must be porous enough without being too much so, and the glaze must be very fusible in order that it may penetrate into the pores where the chemical reactions will take place. These properties, which are sometimes contradictory, oblige us to modify the mixtures, and to choose

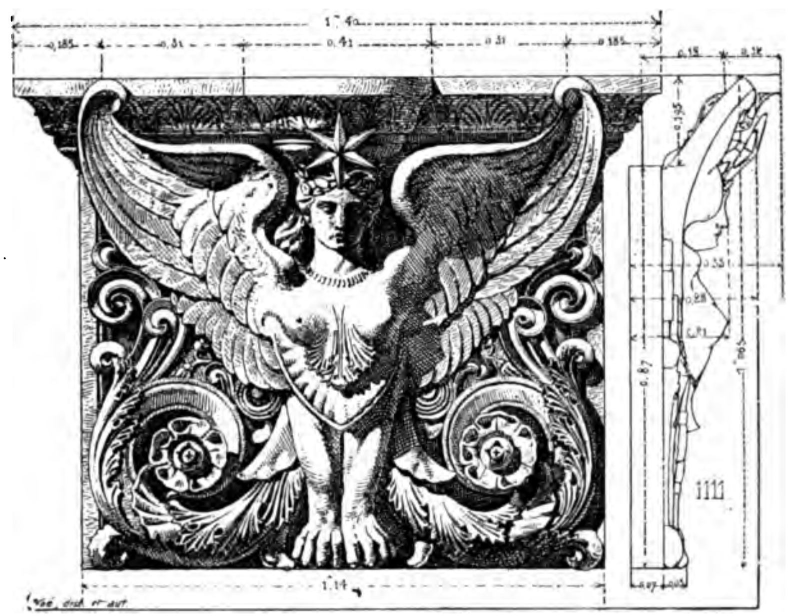


Fig. 865.—Sphinx in the Gate of the Palais des Beaux-Arts at the Exhibition of 1878, executed by Lœbnitz from the Designs of Paul Sédille, the Architect.

a happy mean. Thus the silicious glazes preferred for aluminous pastes are necessarily not very fusible; the quantity of silica must then be reduced or, if possible, an energetic flux added.

The preparation of the pastes and their moulding is carried out as in the case of non-enamelled pastes.

The glazes are usually applied to the unbaked paste, either by immersion, sprinkling, or with the brush, or, for large monochrome surfaces, by insufflation. Some more delicate pieces are glazed when in biscuit or slightly heated.

Fig. 866.—*La Vérité*, a Decorative Panel from the Porch of the Palais des Beaux-Arts, on the Garden Side, at the Exhibition of 1889 (Lœbnitz).

The firing takes place in the usual faïence kilns, either bare or with appropriate stacking, and most frequently in saggers. Certain decorations require the muffled kiln.

The decorative effects obtainable are increased by combining opaque enamels with transparent enamels, or with dull enamels produced by adding a large proportion of silica to the glaze, and so diminishing its fusibility. Instead of applying the enamel to all parts of the piece, the natural colour of the clay may sometimes be left visible in certain places, or it may be covered with gold-leaf, which thus adds its brilliancy to that of the enamels.

Lœbnitz was one of the first to make ceramic products of this kind, and the earliest example was the decoration of the monumental gate forming the entrance to the French Beaux-Arts at the International Exhibition of 1878; Fig. 865 shows a part of it.

The same ceramist executed in a similar style the large panels which decorated the porch of the Palais des Beaux-Arts at the Exhibition of 1889 (Fig. 866).

That Exhibition (of 1889) presented a considerable choice of the most diverse ceramic products. The Palace of the Argentine Republic (Fig. 867) especially attracted attention by its remarkable ornamentation, consisting only of iron and clay, and designed by the architect Bellu.

The panels forming the bases of the windows (Fig. 871), the metopes (Fig. 870), entrance arcades, knobs and tops of façades (Figs. 868, 869), were executed by Lœbnitz. Muller had

Fig. 867.—Palace of the Argentine Republic at the Exhibition of 1889 (M. Ballu, Architect).

provided bricks and enamelled friezes, such as those on the façade pillars, called " Écus " and " Chats."

Fig. 873 represents an enamelled frieze with dull ground,

"grand feu," executed by Muller, and Fig. 874 is a decorative panel with dull ground and reliefs set off by enamels.

Private buildings, particularly those intended for special purposes, such as cafés, restaurants, etc., are also decorated with enamelled pottery. It would be easy to mention a great number

Fig. 868.

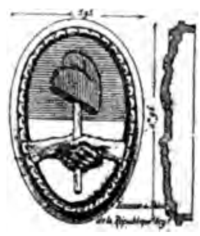
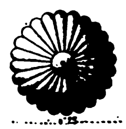


Fig. 869.

Fig. 870.



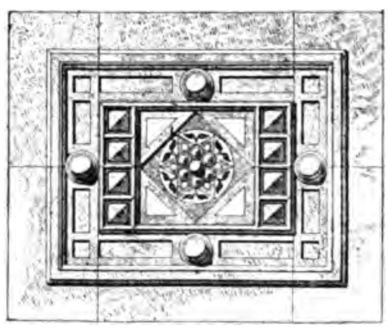


Fig. 871.

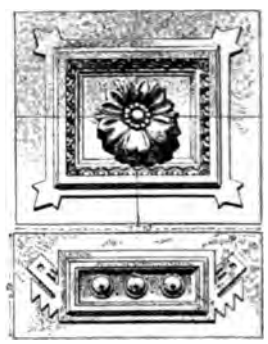


Fig. 872.

Figs. 868 to 872.—Enamelled Terra-cotta Decorations on the Palace of the Argentine Republic (executed by Lœbnitz).

of examples in Paris of this use of decorative pottery, which is applied inside in the form of panels of facing quarries, and outside in various forms.

Many of these decorations, however, are not irreproachable as regards harmony of colours, and the effects produced are not always in the purest taste. As examples we may mention the

design of the entrance gate of the Bal Bullier on the Boulevard Saint-Michel, and the façade of the Café Riche on the Boulevard des Italiens. Fig. 875 represents the design of one of the pillars of this café; the background is formed of enamelled bricks; the figures and bricks, executed by Lœbnitz, are covered with

Fig. 873.—Enamel Frieze, "Grand Feu."

Fig. 874.—Decorative Panel on Dull Background.

(Manufactured by Émile Muller.)

stanniferous opaque enamels in accordance with the traditions of the firm, which has remained faithful to this old-fashioned enamel, and has, so to speak, made a specialty of it.

The English naturally make great use of architectural faïences in the form of friezes (Figs. 876, 877), decorative panels (Figs. 878 to 880), etc.

Fig. 875.—*La Danse*, executed in Pottery by Lœbnitz.

§ 2. STONEWARES.

The use of this material in architectural decoration is, in Europe, of recent date; judging from the results obtained, it would seem likely that this substance will take an important place in the ceramic decoration of future buildings.

Stoneware will not take the place of terra-cotta ; it will stand

side by side with it, and its presence will introduce a special feature into the general ornamentation of buildings. It would

ENAMELLED POTTERY OF ENGLISH MANUFACTURE (ENAMELLED EMBOSSED TILES).

Fig. 876.

Fig. 877.

Fig. 878. Fig. 879

Fig. 880. Fig. 881. Fig. 882.

Figs. 877, 879, 881.—Carter & Co. Figs. 876, 878, 880, 882.—Maw & Co.

therefore be a mistake to try to make one an imitation of the other; let us rather leave to each its own qualities and characteristics.

Imperviousness and hardness are the valuable advantages which stoneware has over terra-cotta, but these are counterbalanced by the difficulties of manufacture, and especially by the liability of stonewares to lose their shape at that moment in firing when softening takes place. In the case of artistic pieces of curved shapes, this deformation is avoided with comparative ease.

The plasticity of stoneware pastes facilitates their moulding and even modelling by hand.

The material is more or less coloured according to the purity of the ingredients used; it may be left dull or be covered with a glaze. The latter is generally transparent, as opaque enamels do not give good results.

The silico-alkaline glaze (sea-salt at a high temperature) gives satisfactory results in certain cases, but it is often advisable to use glazes which are fixed by a second firing at a lower temperature, such as soft glazes and even transparent enamels, for the colour used in the paste or glaze allows of very pleasing and varied effects being obtained. For instance, coloured dips may be applied to the stoneware and afterwards developed by a felspar glaze; by firing successively in reducing and oxidising atmospheres, different tints are obtained, which are the more charming as they are unexpected. By taking dips which melt at a lower temperature than that of the firing of stoneware, colours of pleasing appearance are produced; the Chinese and Japanese have made frequent use of this process.

The English are past masters in the manufacture of common and artistic stoneware; the firm of Doulton is particularly famous for its productions, which are remarkable for their finish, good taste, and excellent quality.

In France, the firm of Émile Muller has for some years manufactured decorative stoneware. As long ago as the Exhibition of 1889 it produced several enamelled friezes for the Palace of the Argentine Republic, one of which, called "des Chats" (Fig. 867, to the left on the pillars), was quite a masterpiece. Since then, at Chicago, and at the different salons in Paris, it has shown other specimens (frieze of the Archers

and of the Lions of Darius, reproduction of the works of Falguière, etc.) which exemplify the pleasing effects of decorative stoneware. We cannot lay too much stress upon these interesting attempts, which are evidence of an earnest endeavour to endow architecture with a new element of decoration. Experiments of this nature are very costly, and the men who initiate them rarely, even in case of success, gain great pecuniary benefit from their work.

In a less pretentious manner stoneware has been turned to account for the manufacture of decorated balustrades, etc. Its durability renders it valuable in certain cases.

§ 3. PORCELAINS.

Several attempts have been made to introduce porcelain into the facings of walls. MM. Parvillée, the skilful ceramists, had exhibited in 1889 some very interesting specimens of decoration executed on a special porcelain, the same product which they have successfully applied to the manufacture of porcelain articles for electrical purposes. The cost of the primary materials and certain difficulties in the manufacture have probably prevented them from continuing their experiments, and this is much to be regretted.

We know that porcelain is extensively used in the far East for the decoration of both the inside and outside of walls.

CHAPTER V.

Sanitary Pottery.

This is a name given to certain ceramic products used for household purposes, including more particularly pipes of glazed stoneware, sinks, urinals, basins, etc.

As is always the case with regard to pottery, these articles had been manufactured and used in England long before we decided to adopt them. All visitors to England are struck with the way in which our neighbours have profited by these applications of pottery to the hygiene and health of dwellings.

As before, we shall study these different products according to their forms and uses.

Stoneware Pipes.

For a long time these pipes were made exclusively in England, and the products which the firm of Doulton sent all over the world from that country were so perfect that it seemed impossible to imitate them. The fact is, that besides physical appearance, shape, and glaze, another quality is indispensable for pipes—elasticity; without it the pipes are brittle, and will crack in the ground merely in consequence of the vibrations of traffic or other causes.

It is only in the last ten years that this manufacture has been introduced into France. In spite of technical and economic difficulties, which it has surmounted, the industry has developed to such an extent that the consumption of English products has been considerably reduced.

The principal factories in France are at Pouilly-sur-Saône

(Jacob et Cie.), at Boulogne (Société des produits céramiques), at Rambervilliers, at Breteuil-sur-Iton (Rousseau et Cie.), etc.

Others of less importance are scattered through the North of France. Belgium and Germany also make many pipes.

Manufacture.—They are made exactly like pipes of ordinary clay, but from special pastes which fire into stoneware. The proportions of the different clays used in these pastes depend upon the clays available; it is different in each factory, since the materials employed are variable.

The paste usually consists of a refractory clay mixed with felspar or pegmatite, and sometimes, with a view to economy, other commoner clays. Vitrifiable clays are also used mixed with antiplastic substances (pulverised fragments of pipes or saggers).

The more refractory the clay is, the less likely is the pipe to lose shape in firing; but then there is no vitrification, and, as in the case of English pipes, the pieces retain a certain degree of porosity. This slight porosity has no effect on the quality of the products.

The expression of straight or slightly curved pipes is effected by machines similar to those already described (p. 343); pipes of special shape are made in plaster moulds.

These special shapes are very numerous (Figs. 883 to 903); in addition to single (Fig. 884), double (885, 886), and treble (Fig. 887) branched pipes, conical (Fig. 888) pipes are also made for connecting two conduits of different diameter, also opercular pipes (Fig. 890), the upper parts of which are removable so as to allow of cleaning the interior. The drainage pipes (Fig. 893) and drains (Fig. 902) for carrying away flood-gate water do not present any difficulties. The siphons (Figs. 897 to 901) are moulded in two parts which are afterwards welded together.

Moulding, drying, and polishing are carried out as has been described in the case of pipes of ordinary clay.

Firing.—The firing of stoneware pipes takes place at a high temperature in round reverberatory kilns (Fig. 206), or semi-continuous kilns, or in continuous kilns with several firing chambers (Fig. 231).

The semi-continuous kilns are of rectangular shape and are composed of a series of compartments occupying the whole breadth of the kiln and separated by walls. Communication

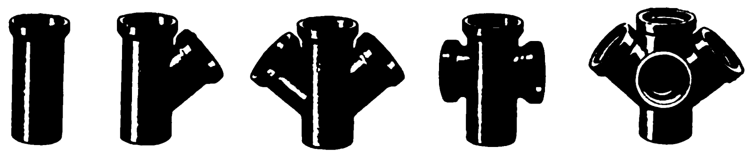


Fig. 883. Fig. 884. Fig. 885. Fig. 886. Fig. 887.

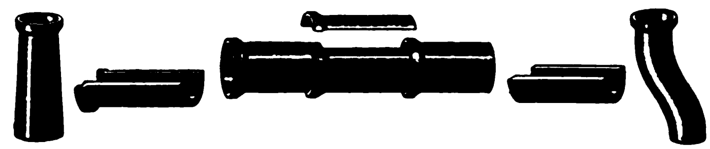


Fig. 888. Fig. 889. Fig. 890. Fig. 891. Fig. 892.

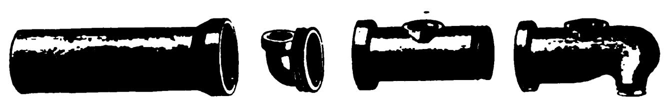


Fig. 893. Fig. 894. Fig. 895. Fig. 896.

Fig. 897. Fig. 898. Fig. 899. Fig. 900.

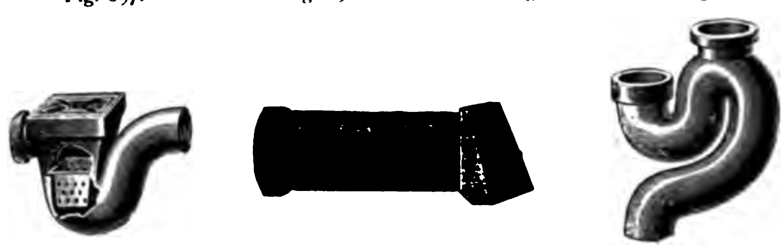


Fig. 901. Fig. 902. Fig. 903.

Figs. 883 to 903.—Stoneware Pipes of Different Shapes.

is made by means of openings in the floors of the chambers. The furnaces, four in number, are placed in the angles of each compartment; work is carried on inside the kiln, through two doors or gaps situated opposite to one another.

A "camp" of bricks is laid upon the floor of the kiln, and upon this the pipes are placed vertically, some inside others. The socket of the large pipes is protected by a cover which surrounds it and serves, so to speak, as a sagger. The space between the pipes should be large enough to allow the gases to circulate freely, thus ensuring a uniform glaze when salting takes place.

The fire is lighted at one end of the kiln, and the gases pass through several full compartments before reaching the chimney. The firing is effected at a high temperature and ends with the *salting*. This operation, which was used for the first time at the end of the 17th century by the English brothers Flers, consists of throwing sea-salt into the kiln when the maximum temperature of firing is reached. This temperature varies from 1300° to 1500° C. according to the nature of the pastes; upon contact with the silica of the pottery the salt (NaCl) splits up into chlorine and sodium, which latter combines with the silica, forming a complex fusible silicate; this is the glaze. The freed chlorine decomposes the water-vapour present in the products of combustion, and escapes into the air in the form of hydrochloric acid (HCl).

This explanation is in accordance with our knowledge of chemical reactions, but it is not sufficient to account for the facts observed by Salvetat, namely—

1. That dull stonewares, not salt-glazed, contain less silica (10 per cent. at least) than the glazed stonewares; 2. that sea-salt glazing requires that there should be an excess of silica in the paste; 3. that the glazing of the stonewares scarcely increases at all the quantity of alkali which they naturally contain.

In order, then, that the salting operation may be successful, the pastes must be silicious; aluminous pastes, that is to say pastes of basic nature, cannot receive a glaze in this manner.

The salt is either introduced direct through the furnaces or by orifices in the roof; about a kilogramme and a half of salt is required for each cubic metre of stacked products.

This quantity is introduced gradually, for the volatilisation

of the salt, combined with the entrance of the cold air, considerably lowers the interior temperature of the kiln, and it must regain its maximum before salt is again introduced.

The walls of the kiln also become covered with glaze, and repeated operations at last completely disintegrate them ; their durability may be increased by constructing them of materials of basic nature (alumina, limestone, magnesia). After salting, all the orifices of the kiln are closed, it is allowed to cool slowly, and then emptied.

Applications.—The use of glazed stoneware pipes has become important in modern sanitary installations: canalisation and evacuation of flood-gate water, collection and conduction of spring-water, etc.

The advantages of stoneware pipes over other pipes of cast-iron, cement, etc., are that they are unaffected by damp, completely impervious and smooth in surface, and proof against the acids and other corrosive matter contained in the sluice-waters.

Pipes of moderate thickness and with collar-joint will not support great pressure, and are therefore only used for drainage and evacuation of water. For conduits which have to bear considerable pressure, such as those for collection of spring-waters, thick pipes with socket-joint are used.

The first, which are much more extensively used than the second, are usually laid in trenches, with a *minimum* slope of one in fifty if there is no flush; it may be reduced in case of there being fairly frequent flushes, but it is always prudent to give the greatest slope permitted by the configuration of the ground.

The joints are made with cement which takes with moderate rapidity and is mixed with sand; cements should be avoided which swell and would burst the collars. Well-made joints are an *essential condition* of good canalisation.

On the other hand, it is not sufficient that the joints should be water-tight and well made, they must also be easily removed when, in consequence of rupture or any other cause, a pipe has to be replaced. These contradictory conditions are difficult

to fulfil, and the problem of finding a good joint for stoneware conduits is always being studied. We give as a suggestion

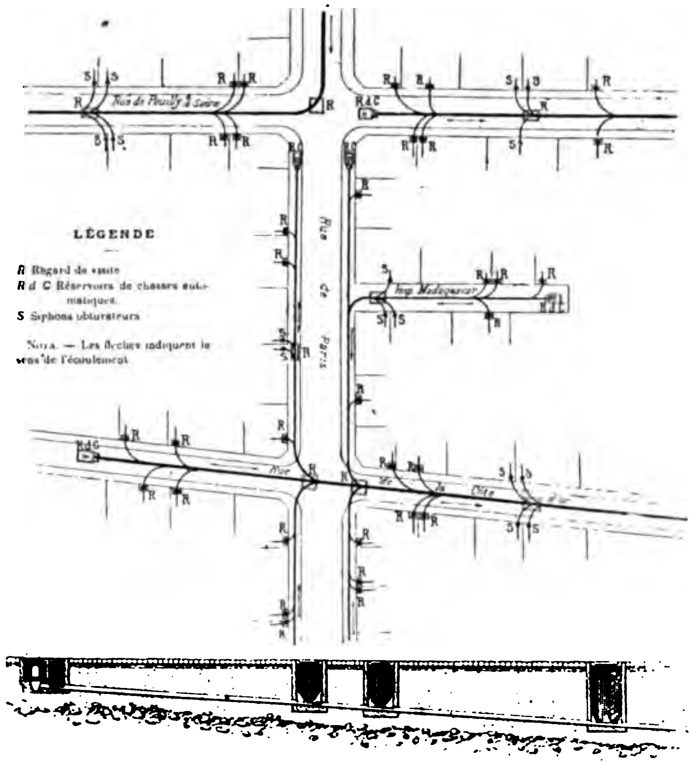


Fig. 905.—Plan of a System of Stoneware Drain-pipes.

DESCRIPTION.

R. Inspection opening.
R d C. Automatic flush reservoirs.
S. Covering siphons.

Note. The arrows indicate the direction of flow.

(Fig. 905) the plan of a system of drains formed of stoneware pipes.

Sinks.

These are made of finer stoneware paste than that used for pipes, for they receive a glaze.

The moulding is done by hand, and the shape is usually

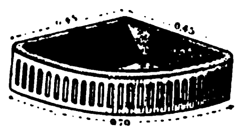
square (Fig. 906) or angular (Fig. 908) for corner sinks. The firing takes place in reverberatory kilns, the sinks being protected by saggers. Glazing is generally effected by salting, or, when the paste allows of it, with alkalino-boracic plumbiferous enamels, which are sometimes made opaque; more often, however, the colour of the paste, which is slightly yellowish, is left visible.

STONEWARE SINKS.

Fig. 906.

Fig. 907.

Fig. 908.



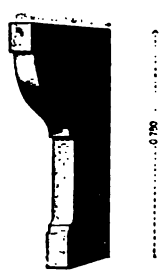


Fig. 909.

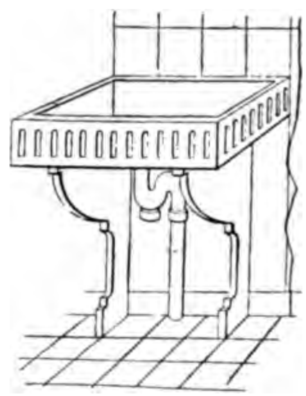


Fig. 910.

Fig. 906.—Rectangular Sink (Soc. des produits céramiques de Boulogne). Fig. 907.—Rectangular Sink with Flutings (Jacob et Cie.). Fig. 908.--Angular Sink (Rousseau et Cie.). Fig. 909.—Stoneware Bracket (Boulogne). Fig. 910.—Sink on Bracket with Siphon (Jacob et Cie.).

Applications.—The advantage of stoneware over stone sinks is their complete imperviousness, which renders them easy to keep clean.

The fixing of them depends upon local conditions; when the sink is placed against a wall, it is supported by brackets of the same substance (Fig. 909). The evacuation pipe is provided with a siphon and discharge plug.

PARTICULARS OF STONEWARE SINKS.

	Dimensions in Centimetres.			Weight in Kilogrammes.	Price in Francs.	Remarks.
	Length.	Breadth.	Interior Depth.			
Rectangular Sinks.	45	35	6	12 to 14.5	**12**	The brackets are 0.75 m., 0.78 m., or 1 m. in height, and cost 30 francs the pair.
	50	40	7	19	**14.50**	
	60	40	8	24 to 27	**18**	
	65	45	8	12	**21.50**	
	75	45	9	34 to 35	**24**	
	80	55	9	46 to 50	**31.50**	
	90	55	10	50 to 52	**40**	
	100	60	10	65 to 67	**46**	
	110	60	10	64 to 73	**58**	
Angular Sinks.	40	63	5	11	**9**	Prices taken from the catalogues of Jacob et Cie., Société de Boulogne, and Rousseau et Cie. Reduction made for large orders.
	45	70	6	...	**15**	
	50	78	6	16	**13**	
	55	85	8	24	**17**	
	60	95	10	27	**21**	
	70	55	10	25	**17**	
	75	60	10	29	**21**	

Urinals, Seats, and Pans.

These are made either in enamelled stoneware, felspar faïence, or even in porcelain. In the last two cases, the pastes are white and delicate, and receive a glaze similar to those applied to faïences and porcelains.

Fig. 911.

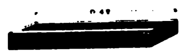


Fig. 912.

Fig. 913.

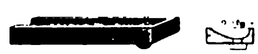


Fig. 914.

Fig. 915.

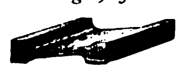


Fig. 916.

Fig. 917.

Fig. 918.

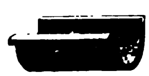
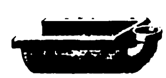


Fig. 919.



Figs. 911 to 919.—Enamelled Stoneware Kennel-stones for Urinals

Figs. 911, 912, and 913 represent block kennel-stones of white enamelled stoneware, serving to carry off the urine from the floor. The end-piece (Fig. 913) has a cover. The stoneware kennel-stones (Figs. 914, 915, 916) are of different

shape but are used for the same purpose. Figs. 917, 918, and 919 represent trough urinals and are also of enamelled stoneware; the entrance piece (Fig. 919) has a tube for admis-

Fig. 920.

Fig. 921.

Fig. 922.

Figs. 920 to 922.—Bracket Urinals (Jacob et Cie., Soc. céram. de Boulogne).

sion of water, and the issue piece (Fig. 917) has another for carrying off the liquids.

"À LA TURQUE" SEATS OF ENAMELLED STONEWARE.

Fig. 923.

Fig. 926.

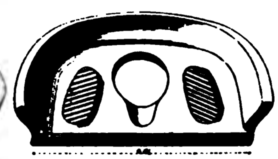


Fig. 927.

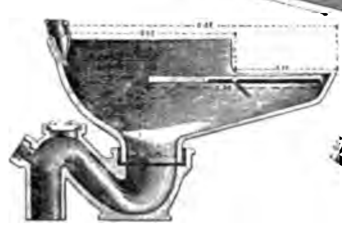


Fig. 924.

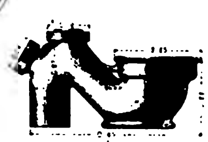


Fig. 925.

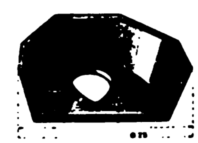


Fig. 928.

Figs. 923 to 925.—Société des produits céramiques de Boulogne.
Figs. 926 to 928.—Rousseau et Cie.

The bracket urinals (Figs. 920 to 922) are of white enamelled stoneware or of faïence, and cost from 20 to 30 francs each.

The seats called "à la turque" (Figs. 923 to 928) are of various

shapes. The one in Fig. 923 is of enamelled stoneware, and its accessories comprise a galvanised grating, a bronze water-spout, and a siphon of enamelled stoneware (Fig. 925). The complete apparatus (Fig. 923) is quoted at 137 francs.

The canted seats (Fig. 928), circular (Fig. 927), or school seats (Fig. 926) are fitted up in different ways. Figs. 929 and 930 represent a good arrangement which ensures a thorough washing of all the sides of the closet. The partitions are built

INSTALLATION OF AN "À LA TURQUE" SEAT (Soc. céramique de Boulogne).

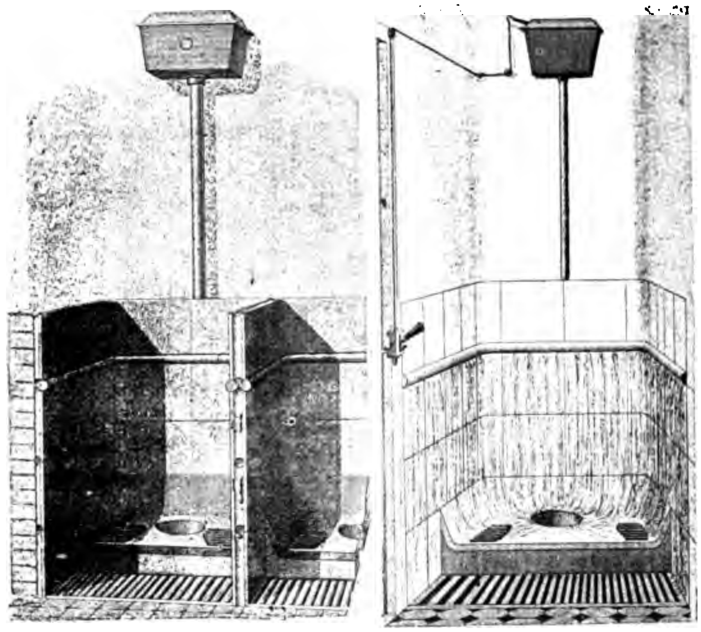


Fig. 929.—Seat before Cleaning. Fig. 930.—Seat during Cleaning.

of enamelled "bardeaux," and the sloping surface washed is itself of enamelled stoneware. This arrangement gives good results but requires a great deal of water; each compartment, including the reservoir but not fixing, costs 300 francs.

Figs. 931 and 934 represent other types of installations of common closets with "à la turque" seats fitted up by the engineers in several military establishments, notably at the École polytechnique. The seats in installation 932 are laid

Fig. 931.

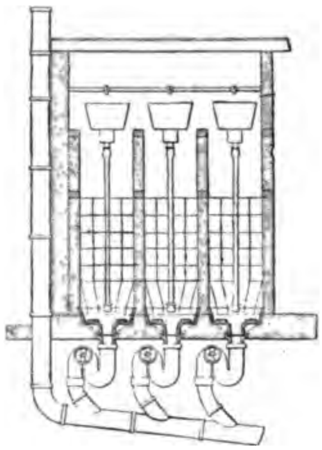
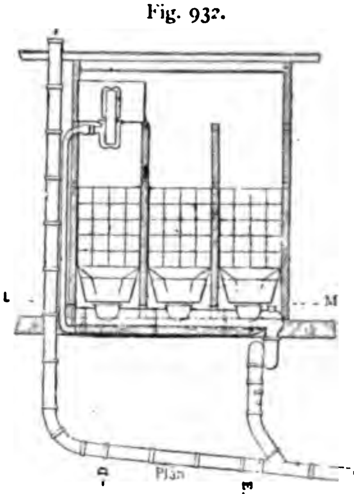


Fig. 932.



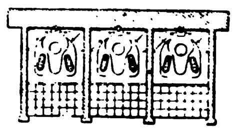


Fig. 933.

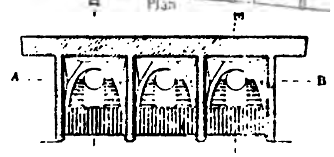


Fig. 934.

Figs. 931 to 934.—Types of Installation of Common Closets with "à la Turque" Seat (Jacob et Cie.).

PANS OF VARIOUS KINDS.

Fig. 935.

Fig. 936.

Fig. 937.

Fig. 938.

Fig. 939.

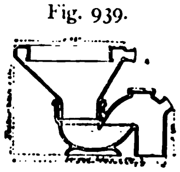


Fig. 940.

Fig. 941.

Fig. 942.

Fig. 943.

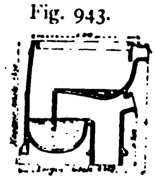
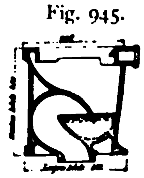


Fig. 944.

Fig. 945.



Figs. 935, 936.—Soc. céram. de Boulogne. Figs. 937 to 941.—Jacob et Cie.

over a collector which is formed of the several detached pieces represented in Figs. 894, 895, 896. The flush water enters at one end and issues at the other, while a siphon prevents communication between the air and the drain.

The pans are made of fine enamelled stoneware or of porcelain, and are moulded by hand. They may consist of pan

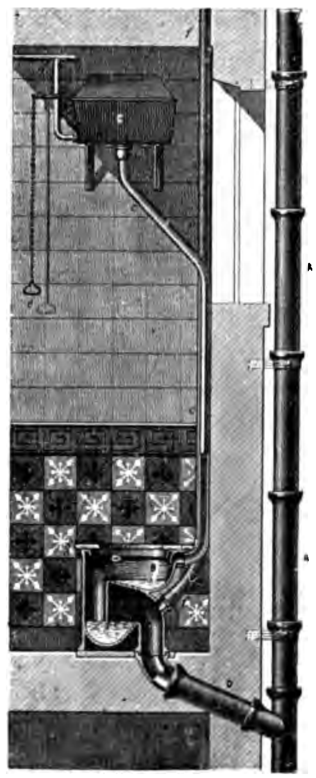


Fig. 946.—Installation of a Closet with Flush-pan (Soc. céramique de Boulogne).

and siphon in a single piece (Figs. 935, 938, 941, 945), or of pans with separate siphons (Figs. 939, 940). Some have direct flush (Figs. 939, 941, 945), others have interrupted flush (Figs. 936, 943). The price of a pan with siphon varies from 40 to 60 francs according to the decoration.

The installation of a closet with pan and flush to the drain is represented in Fig. 946; it comprises: a descent pipe A,

a pan B, a flush reservoir containing 10 litres of water, a flush-pipe C, a feed-pipe D with pull E, a ventilation-pipe F, and a hinged seat G of varnished wood.

The apparatus for an installation of this kind, namely: pan, mahogany hinged seat, flush reservoir with chain and pipes, costs from 50 to 170 francs, according to the style of the pan. We must add to this price the cost of fitting up, and the facing of the walls when they are faced with quarries.

Drinking-fountains—Washstands.

These are made of white enamelled stoneware or of porcelain. Some (Figs. 948, 949) have a siphon below; in others the siphon is of metal and is fitted to the evacuation pipe.

DRINKING-FOUNTAINS—WASH-STANDS.

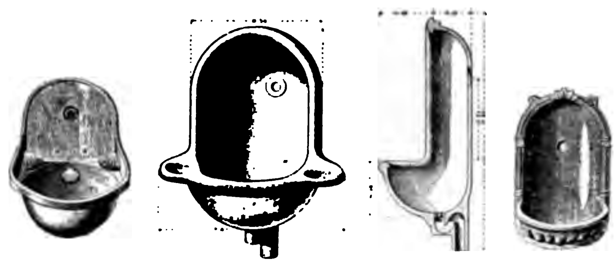


Fig. 947. Fig. 948. Fig. 949. Fig. 950.

Figs. 947 and 950.—Jacob et Cie. Figs. 948, 949.—Soc. céram. de Boulogne.

The price of porcelain basins (Figs. 947, 950) varies from 30 to 45 francs for a diameter of 0.26 m. or 0.30 m.; that of drinking-fountains varies from 35 to 80 francs according to size and ornamentation. They are also made in felspar faïence.

THE END

BIBLIOGRAPHY.

AMÉ . . . . . *Les carrelages émaillés du moyen âge et de la Renaissance.* Paris, 1859.

BASTENAIRE-DAUDENART . L'Art de fabriquer la faïence blanche recouverte d'un émail opaque. Paris, 1828.

" L'Art de fabriquer la faïence blanche recouverte d'un émail transparent. Paris, 1830.

BATISSIER . . . . *Histoire de l'art monumental.* Paris.

BERTRAND . . . *Les carrelages muraux en faïence,* 1860.

BERTY . . . . *La Renaissance monumentale en France,* Paris, 1864, 2 vol., gr. in-4°.

BONNEVILLE, JAUNEZ, PAUL, etc. La fabrication des briques et des tuiles. Paris, 1879.

BOURGOING . . . Les arts arabes, architecture, revêtements, pavements, 1877.

BOURRY . . . . *Traité des industries céramiques.* Paris, 1827.

BRONGNIART . . . *Traité des arts céramiques,* 3e éd. Paris, 1877, 2 vol. in-8° avec atlas.

CAMPANA. . . . *Antiche opere in plastica.* Rome, 1851.

CARBANIÈRE . . . Dalles et pavés céramiques à base de fer. 1877.

CHABAT . . . . La brique et la terre cuite. Paris, 1886, 2 vol. in-f°, avec planches en couleurs.

CHOISY . . . . . L'art de bâtir chez les Romains. Paris, 1875.

COSTE (PASCAL) . . Architecture arabe. Paris, 1839, in-f°.

DARTEIN (F. DE) . . *Étude sur l'architecture lombarde.* Paris, 1870, gr. in-4°, avec atlas.

DECK (TH.) . . . La faïence. Paris, 1887.

DEGEN (LOUIS). . . Les constructions en briques, 2 vol. in-4° avec planches en couleurs. Paris.

DEMMIN . . . . Histoire de la céramique. Paris, 1871, in-f°.

DESOBRY . . . . Rome au siècle d'Auguste, 4e éd. Paris, 1875.

FARGASSE . . . . L'Italie. Paris, 1836, 3 vol. gr. in-8°.

FERGUSSON . . . The illustrated Handbook of Architecture. London, 1855, in-8°.

FOY (FÉLIX) . . . *La céramique des constructions.* Paris, 1882, 1 vol. gr. in-8°.

GARNIER (E.) . . . Histoire de la céramique, poterie, faïence, porcelaine, chez tous les peuples depuis les temps les plus anciens jusqu'à nos jours, 1883.

GRATRY (AUG.). . . Description des appareils de maçonnerie les plus remarquables employés dans les constructions en briques. Brussels, 1865, 1 vol. in-8°.

GRUNER (LEWIS) . . *The terra cotta of North Italy.* London, 1867.

HITTORFF . . . . *L'architecture polychrome chez les Grecs.* Paris, 1851, 1 vol. in-4°, avec atlas.

KERL-BRUNO . . . *Industries céramiques.*

LACROUX et DETAIN . . Constructions en briques, 2 vol. gr. in-f°, avec planches en couleurs. Paris.

LANGLÈS . . . . *Monuments anciens et modernes de l'Hindoustan.* Paris, 1861, 2 vol. gr. in-4°.

LAYARD (HENRY) . . *Discoveries in the ruins of Nineveh and Babylon.* London, 1853.

LEJEUNE . . . . *Guide du briquetier.* Paris, 3e éd.

NICOLLE . . . . De l'emploi des briques ordinaires, 1 vol. gr. in-4° avec planches en couleurs.

PARVILLÉE (LÉON) . . *Architecture et décoration turques au* XVe *siècle*, 1874.

PLACE (VICTOR) . . *Ninive et l'Assyrie.* Paris, 1867-70.

PLANAT . . . . Encyclopédie de l'architecture et de la construction, 12 vol. gr. in-8°.

RAME (A.) . . . . Étude sur les carrelages historiés du XIIe au XVIIe siècle. Paris, 1855.

RORET (*Encyclopédie*). . Manuel du briquetier. Paris, 1864.

SALVETAT . . . . Leçons de céramique. Paris, 1857, 2 vol.

SCHAYES . . . . Histoire de l'architecture en Belgique.

SEDILLE (PAUL) . . La terre cuite et la terre émaillée dans la construction et la décoration, 1877.

,, Conférence sur la céramique monumentale, 1879.

VERDIER et CATTOIS . . Architecture civile et domestique au moyen âge et à la Renaissance. Paris, 1857, 2 vol. in-4°.

VIOLLET-LE-DUC . . *L'Art russe.* Paris, 1877, 1 vol. gr. in-8°.

,, *Dictionnaire raisonné de l'architecture française du* XIe *au* XVIe *siècle.* Paris, 10 vol. in-8°.

VOGT . . . . La porcelaine. Paris, 1893.

Plate I.—Ceramic Pavement.

PLATE II.—LABOR.

Terra-cotta executed by Émile Muller, from the Design of Michel, for the Porch of the Palais des Arts Libéraux at the Paris Exhibition of 1889.

PLATE III.—JEWELLERY.

Panel of Ceramic Quarries, executed by Deck from the Designs of Ehrmann, for the Amsterdam Exhibition of 1883.

PLATE IV.—PANEL OF CERAMIC QUARRIES.

Executed by the Faience Factories of Creil and Montereau for the Saintes Library.

PLATE V.—PANEL OF CERAMIC QUARRIES.

Executed from the Designs of Schuller by the Faïence Factory at Longwy (D'Huart frères).

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